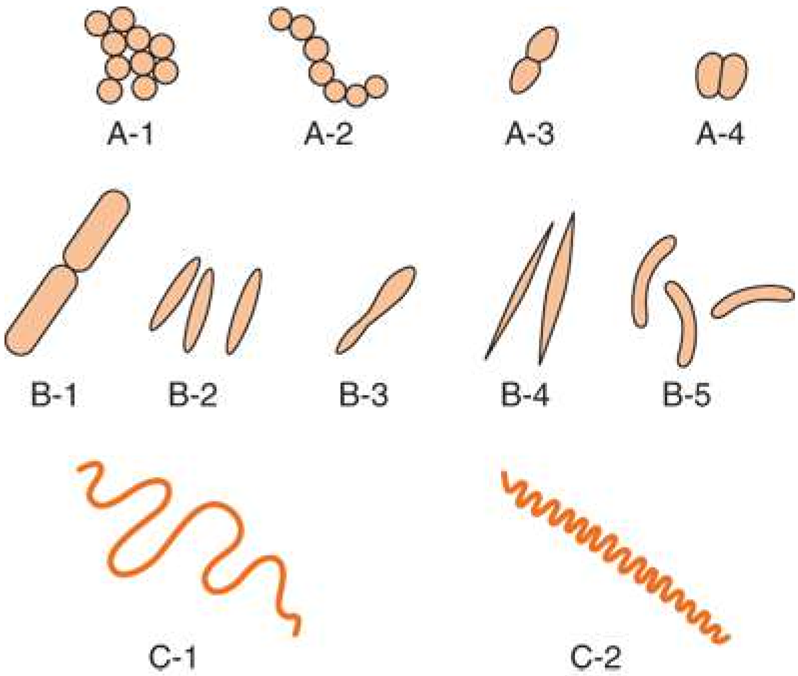
BASIC BACTERIOLOGY

Bacteria are prokaryotes, lacking well-defined nuclei and membrane-bound organelles, and with chromosomes composed of a single closed DNA circle. They come in many shapes and sizes, from minute spheres, cylinders and spiral threads, to flagellated rods, and filamentous chains. They are found practically everywhere on Earth and live in some of the most unusual and seemingly inhospitable places. Evidence shows that bacteria were in existence as long as 3.5 billion years ago, making them one of the oldest living organisms on the Earth.

1- Shape & size of bacteria.

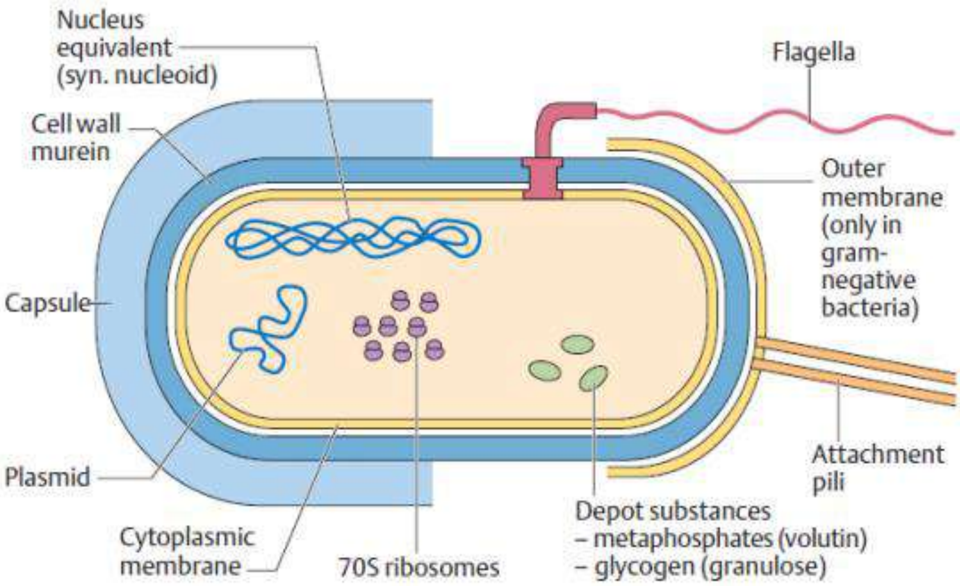
Bacteria are classified by shape into three basic groups: **A-** cocci, **B-** bacilli, and **C-** spirochetes (See Fig below). Some bacteria are variable in shape and are said to be **pleomorphic** (many-shaped). The shape of a bacterium is determined by its rigid cell wall. The microscopic appearance of a bacterium is one of the most important criteria used in its identification. Bacteria range in size from about 0.2 to 5 µm. The smallest bacteria (Mycoplasma) are about the same size as the largest viruses (poxviruses) and are the smallest organisms capable of existing outside a host. The longest bacteria rods are the size of some yeasts and human red blood cells (7 µm).



Source: Warren Levinson: Review of Medical Microbiology and Immunology, 14th Edition, www.accessmedicine.com

2- Structure of bacteria.

The structure of a typical bacterium is illustrated in Figure below



A- <u>Nucleus:</u>

In bacteria, the nucleus generally is called a nucleoid or nuclear body.

1. The bacterial nucleus is not surrounded by a nuclear membrane, nor does it contain a mitotic apparatus.

2. Composition. The nucleus consists of polyamine and magnesium ions bound to negatively charged, circular, supercoiled, double-stranded DNA; small amounts of RNA; RNA polymerase; and other proteins.

The DNA of most bacteria is contained in a single circular molecule, called the bacterial chromosome. The chromosome, along with several proteins and RNA molecules, forms an irregularly shaped structure called the nucleoid. This sits in the cytoplasm of the bacterial cell.

In addition to the chromosome, bacteria often contain plasmids – small circular DNA molecules. Bacteria can pick up new plasmids from other bacterial cells (during conjugation) or from the environment. They can also readily lose them – for instance, when a bacterium divides in two, one of the daughter cells might miss out on getting a plasmid. Every plasmid has its own ‘origin of replication’ – a stretch of DNA that ensures it gets replicated (copied) by the host bacterium. For this reason, plasmids can copy themselves independently of the bacterial chromosome, so there can be many copies of a plasmid – even hundreds – within one bacterial cell.

B- Cytoplasm:

The cytoplasm or protoplasm of bacterial cells is where the functions for cell growth, metabolism, and replication are carried out. It is a gel-like matrix composed of water, enzymes, nutrients, wastes, and gases and contains cell structures such as ribosomes, a chromosome, and plasmids. The cytoplasm contains a large number of solute low- and high-molecular weight substances, RNA and approximately 20 000 ribosomes per cell. Bacteria have 70S ribosomes comprising 30S and 50S subunits. Bacterial ribosomes function as the organelles for protein synthesis. The cytoplasm is also frequently used to store reserve substances (glycogen depots, polymerized metaphosphates, lipids). The cytoplasm when seen in the electron microscope has two distinct areas:

(1) An amorphous matrix that contains ribosomes, nutrient granules, metabolites, and plasmids. (2) An inner, nucleoid region composed of DNA.

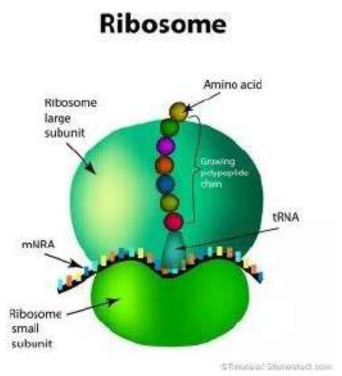
C- Ribosomes:

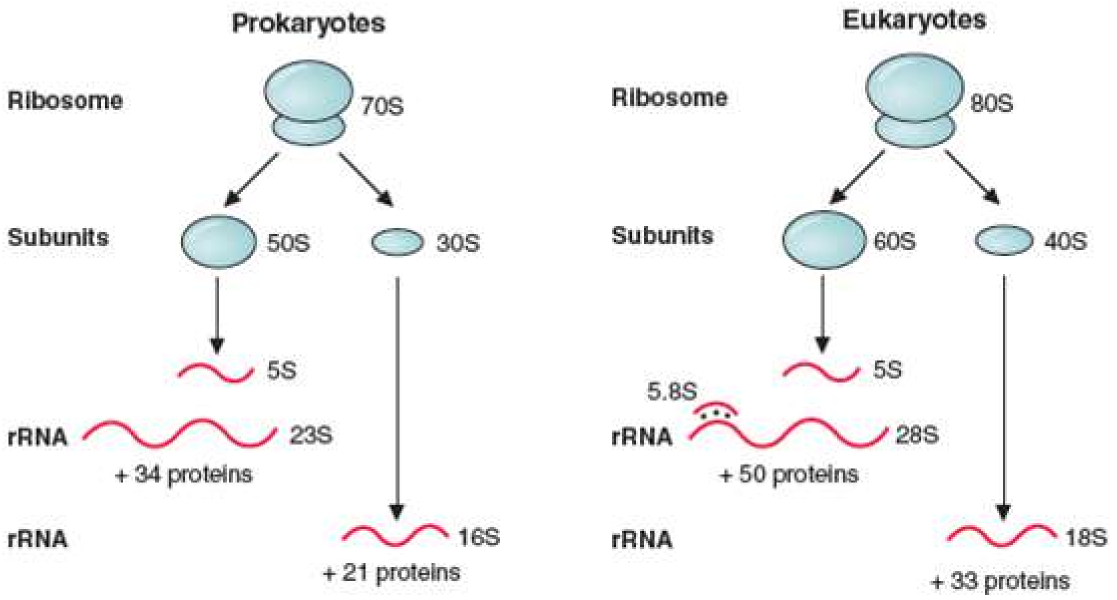
Bacterial ribosomes contain proteins and RNAs that differ from those of their eukaryotic counterparts. Bacterial ribosomes have a sedimentation coefficient of 70S and are composed of 30S and 50S subunits. The genes coding for it are referred to as 16S, and 23S and 5S RNA genes, respectively. **Many antibiotics target ribosomes**, inhibiting protein biosynthesis. Some antibiotics selectively target the 70S ribosomes (e.g., erythromycin), but not 80S ribosomes.

The prokaryotic is comprised of a 30s (Svedberg) subunit and a 50s (Svedberg) subunit meaning 70s for the entire organelle equal to the molecular weight of 2.7×10^6 Daltons. Prokaryotic ribosomes are about 20 nm (200 Å) in diameter and are made of 35% ribosomal proteins and 65% rRNA.

Type	Size	Large subunit (LSU rRNA)	Small subunit (SSU rRNA)
prokaryotic	70S	50S (5S : 120 nt, 23S : 2906 nt)	30S (16S : 1542 nt)
eukaryotic	80S	60S (5S : 121 nt,[15] 5.8S : 156 nt,[16] 28S : 5070 nt[17])	40S (18S : 1869 nt[18])

(Note: The Svedberg unit (S) offers a measure of a particle's size based on its sedimentation rate under acceleration, i.e. how fast a particle of given size and shape 'settles' to the bottom of a solution. The Svedberg is a measure of time, defined as exactly 10^{-13} seconds (100 fs). For biological molecules, sedimentation rate is typically measured as the rate of travel in a centrifuge tube subjected to high g-force).



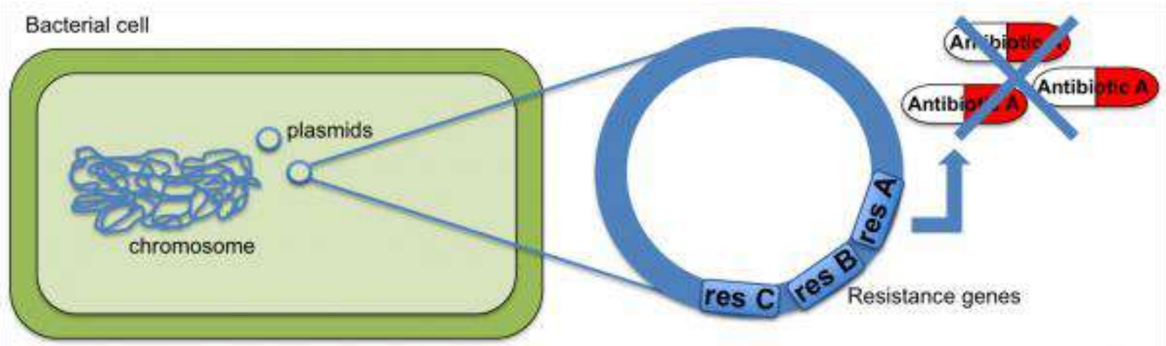


D- Plasmids.

A plasmid is a small, extrachromosomal DNA molecule within a cell that is physically separated from chromosomal DNA and can replicate independently. They are most commonly found as small circular, double-stranded DNA molecules in bacteria.

1. **Plasmids are small, circular, nonchromosomal, double-stranded DNA molecules that are:** a. Capable of self-replication. b. Most frequently extra-chromosomal but may become integrated into bacterial DNA.

2. Function: contain genes that confer protective properties such as antibiotic resistance, virulence factors, or their own transmissibility to other bacteria.



E- Cytoplasmic Cell Membrane.

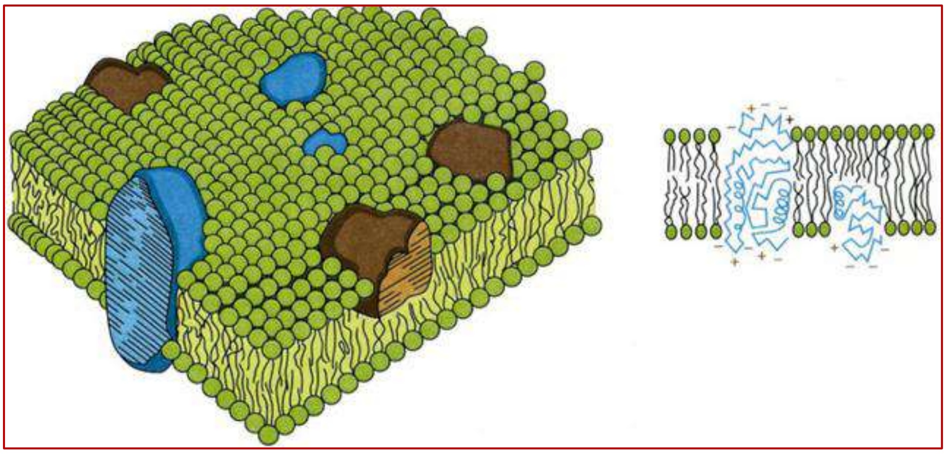
The plasma membrane, also called the cytoplasmic membrane, is the most dynamic structure of a procaryotic cell. Its main function is a s a selective permeability barrier that regulates the passage of substances into and out of the cell. Bacterial membranes are composed of 40 percent phospholipid and 60 percent protein. The composition of a phospholipid bilayer is similar in microscopic appearance to that in eukaryotic cells. They are chemically similar, but eukaryotic membranes contain cholesterol, whereas prokaryotes generally do not. The only prokaryotes that have sterols in their membranes are members of the genus Mycoplasma. The membrane has four important functions:

(1) Selective permeability and active transport of molecules into the cell.

(2) Energy generation by oxidative phosphorylation.

(3) Synthesis of precursors of the cell wall.

(4) Secretion of enzymes and toxins.



F- The Cell Wall.

The cell walls of most bacteria gain their relatively rigid quality from a unique macromolecule called peptidoglycan (PG). The term peptidoglycan is derived from the peptides and the sugars (glycan) that make up the molecule. This compound is composed of a repeating framework of long glycan chains cross-linked by short peptide fragments to provide a strong but flexible support framework (figures below). Peptidoglycan is only one of several materials found in cell walls, and its amount and exact composition vary among the major bacterial groups.

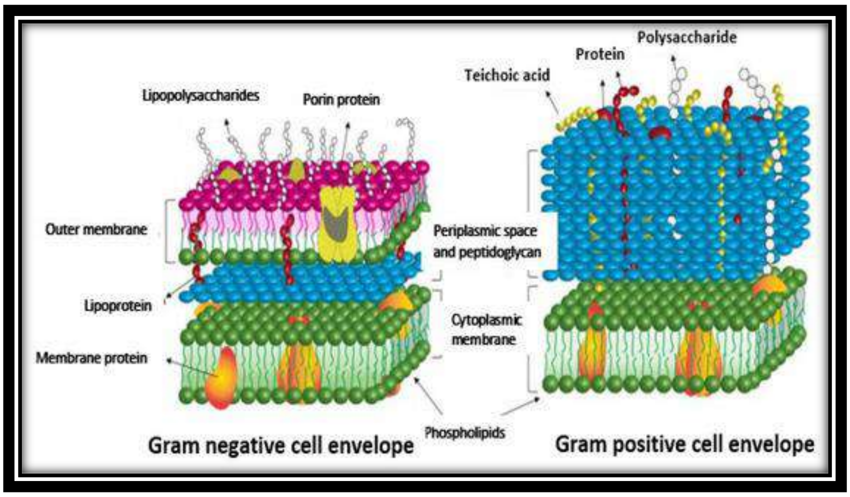
The gram-negative cell wall is more complex in morphology because it contains an outer membrane (OM), has a thinner shell of peptidoglycan, and has an extensive space surrounding the peptidoglycan. The outer membrane is somewhat similar in construction to the cell membrane, except that it contains specialized types of polysaccharides and proteins. As well as, there is lipopolysaccharides (LPS), which are part of the outer membrane of gram-negative cell walls that is responsible for many of the features of disease, such as fever and shock

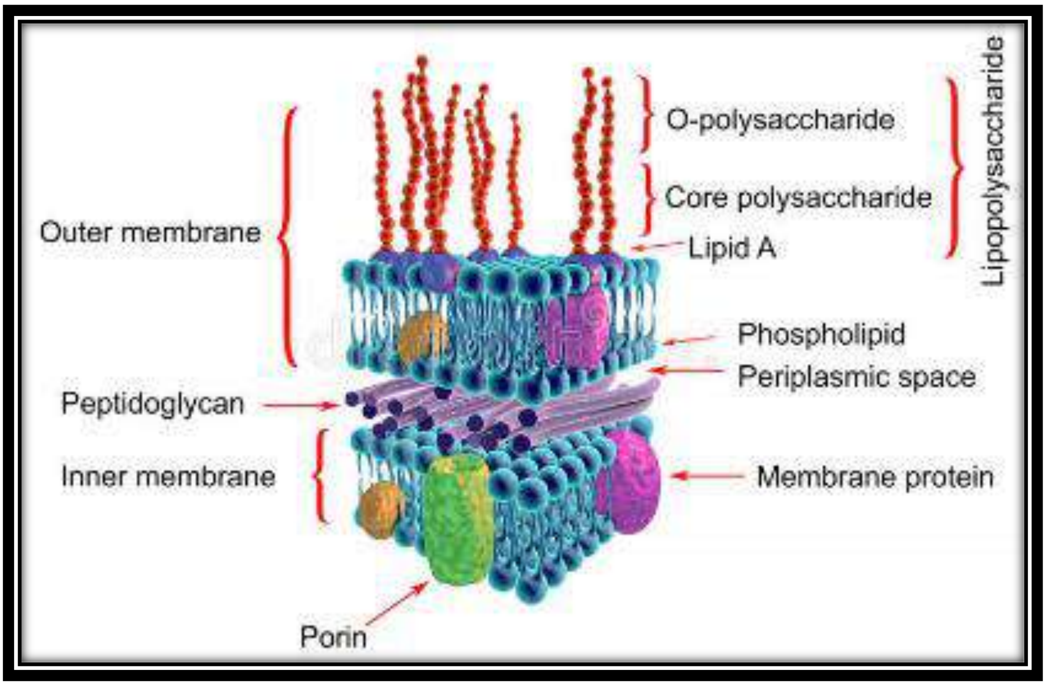
Lipopolysaccharides (LPS), also known as lipoglycans and endotoxins, are large molecules consisting of:

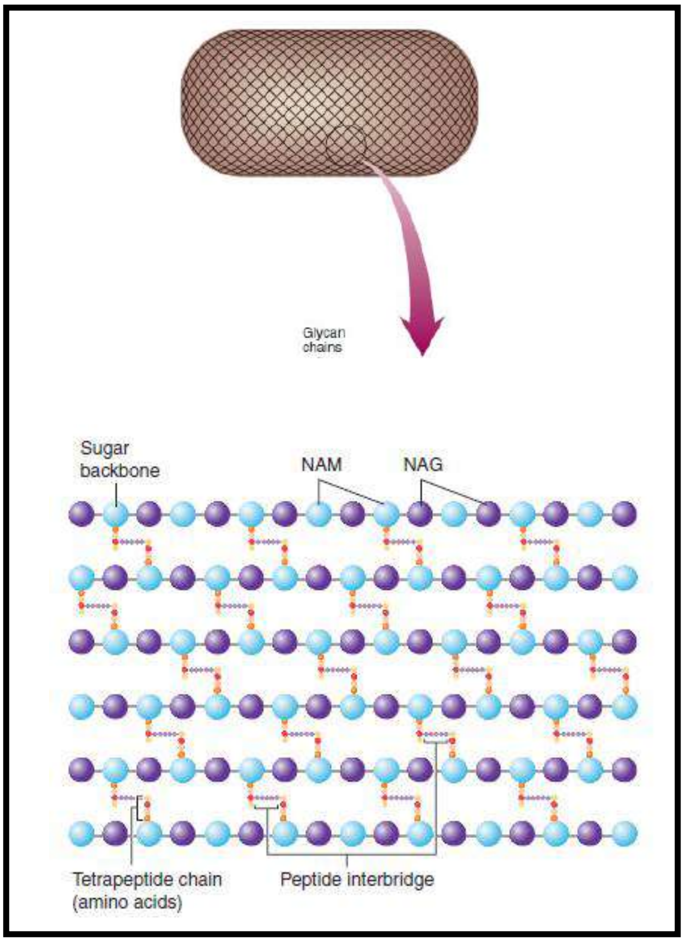
(1) A phospholipid called lipid A, which is responsible for the toxic effects.

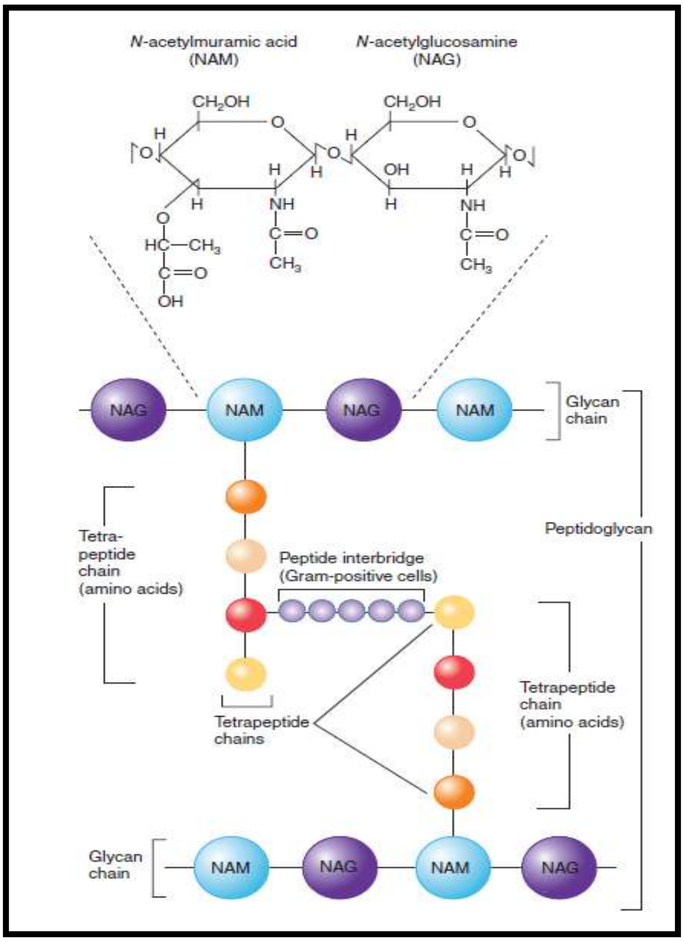
(2) A core polysaccharide of five sugars that is attached to lipid A attached to lipid A by unusual sugars called **keto-deoxyoctulonate**

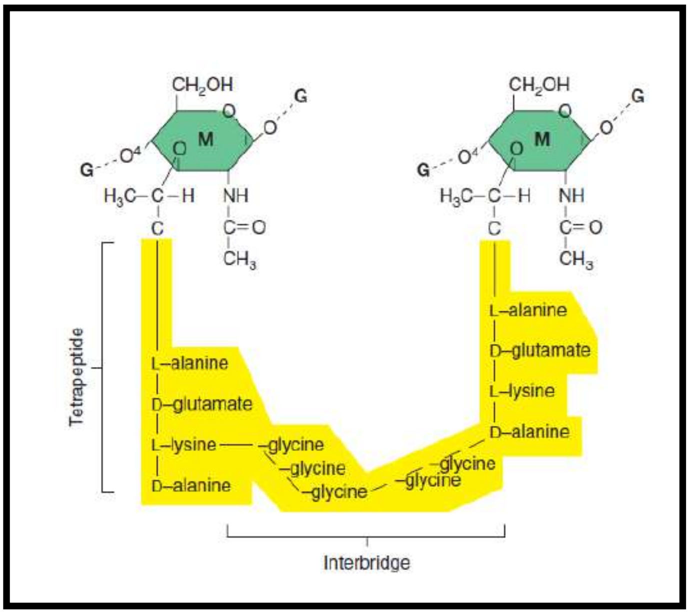
(3) An outer polysaccharide (O antigen) consisting of up to 25 repeating units of three to five sugars.






Glycan chains
Sugar backbone
NAM
NAG
Tetrapeptide chain (amino acids)
Peptide interbridge


N-acetylmuramic acid (NAM)
N-acetylglucosamine (NAG)
NAG
NAM
Glycan chain
Peptidoglycan
Tetra-peptide chain (amino acids)
Peptide interbridge (Gram-positive cells)
Tetrapeptide chains
Tetrapeptide chain (amino acids)


Tetrapeptide
L–alanine
D–glutamate
L–lysine
D–alanine
–glycine
Interbridge

ANTIMICROBIAL CHEMOTHERAPY

Antimicrobial choice is related to the mechanism of drug action in one of the following general categories:

A. Inhibits bacterial cell wall biosynthesis.

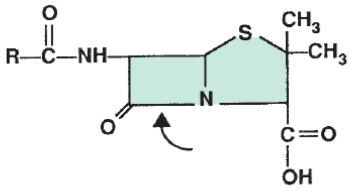
B. Inhibits bacterial protein synthesis..

C. Inhibits bacterial nucleic acid synthesis.

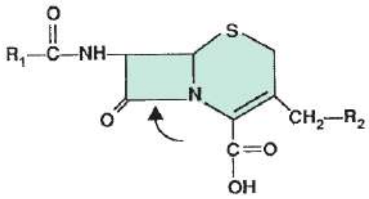
In general, antimicrobial drugs can be either bacteriostatic (inhibit growth) or bactericidal (kill).

A. Inhibitors of Bacterial Cell Wall Biosynthesis

Penicillin is given to patients with an infection caused by bacteria. Some types of bacterial infections that may be treated with penicillin include pneumonia, strep throat, meningitis, syphilis and gonorrhea, according to the National Library of Medicine. Penicillins have a β-lactam ring the integrity of which is required for antibacterial activity.

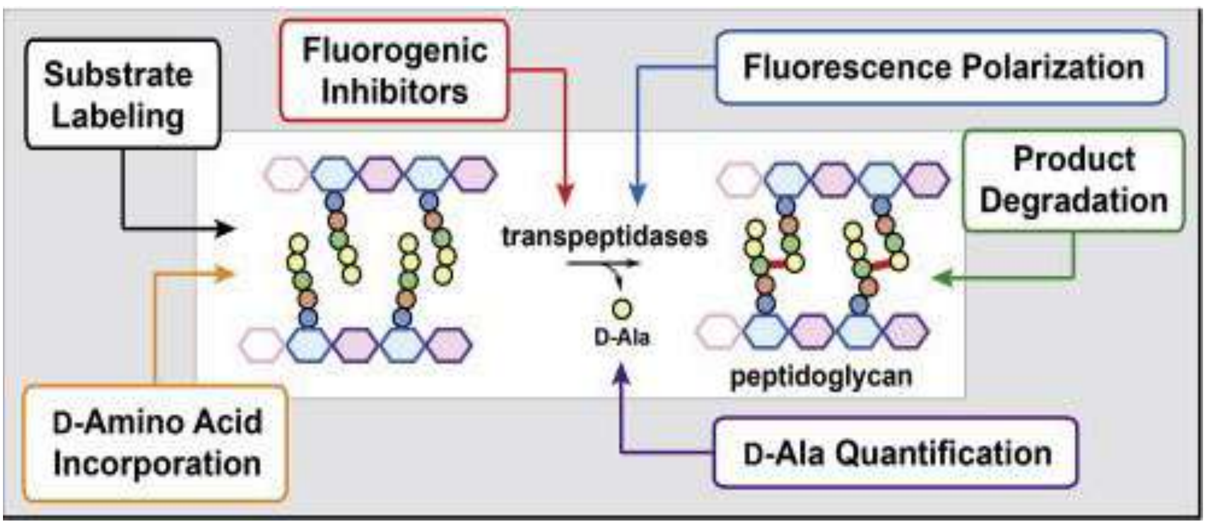


Penicillin nucleus



Cephalosporin nucleus

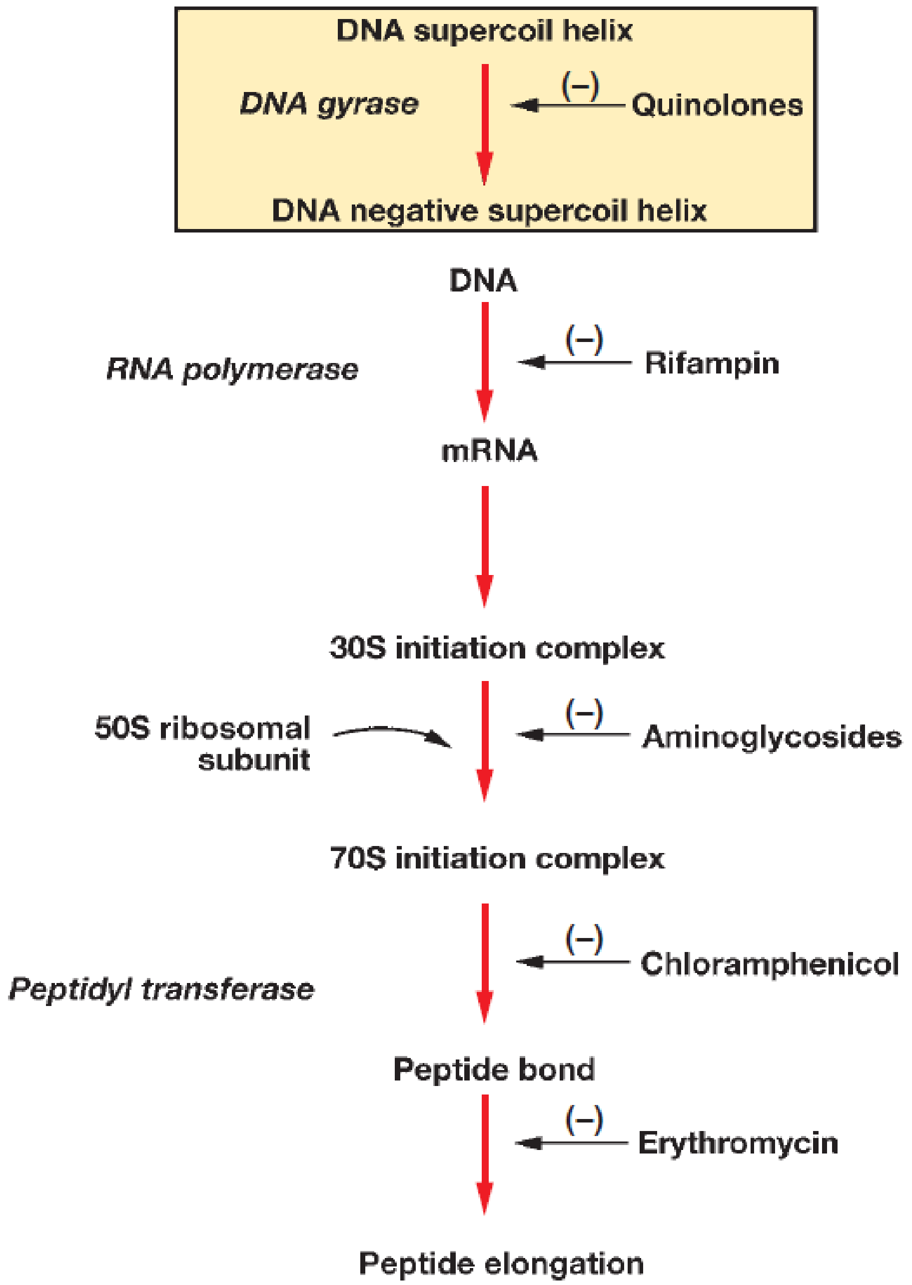
Penicillins inactivate bacterial transpeptidases (or penicillin-binding proteins (PBPs) and prevent the cross-linking of peptidoglycan polymers that is essential for bacterial cell wall integrity. This results in loss of rigidity and a susceptibility to rupture. Penicillins also bind to, and inactivate, penicillin-binding proteins (PBPs) involved in cell wall synthesis.



Penicillins are bactericidal for growing cells. Gram-positive bacteria with thick external cell walls are particularly susceptible. The major cause of resistance is the production of a-lactamases (penicillinases). The genes for β-lactamases can be transmitted during conjugation or as small DNA.

B. Inhibits bacterial protein synthesis.

A protein synthesis inhibitor is a substance that stops or slows the growth or proliferation of cells by disrupting the processes that lead directly to the generation of new proteins. In general, protein synthesis inhibitors work at different stages of prokaryotic mRNA translation into proteins, like initiation, elongation, and termination.

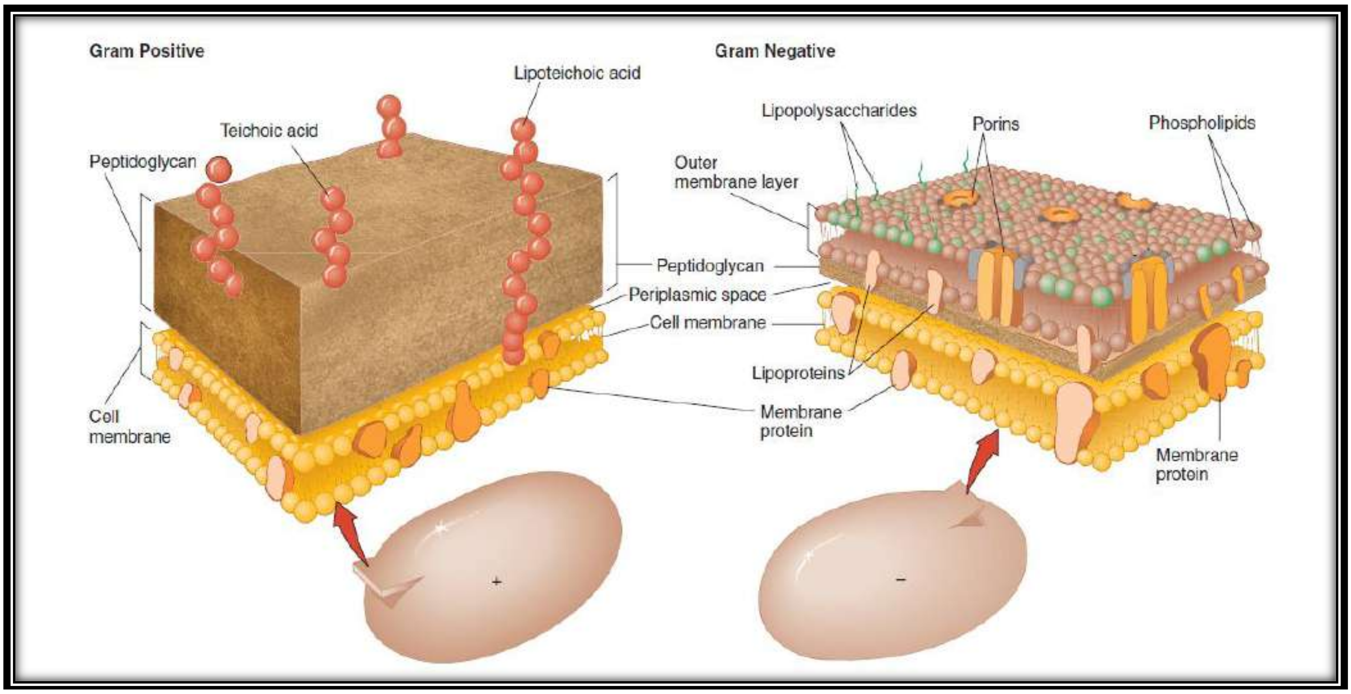


C. inhibition of bacterial nucleic acid synthesis.

The nalidixic **acid**, ciprofloxacin, and norfloxacin, work by inhibiting enzymes that are required for bacterial **DNA synthesis**. So, in contrast to the rifamycins, which **inhibit** transcription of **DNA** into RNA, the quinolones and fluoroquinolones **inhibit DNA** replication.

The antifolate drugs (sulphonamides and dihydrofolate reductase inhibitors) act by blocking the production of thymine. The antifungal agent 5-fluorocytosine interferes with these early stages of DNA synthesis. Through conversion to 5-fluorouracil then to 5-fluorodeoxyuridylic acid (5-F-dUMP).

The anti-human immunodeficiency virus (HIV) drug azidothymidine (AZT). AZT works by selectively inhibiting HIV's reverse transcriptase, the enzyme that the virus uses to make a DNA copy of its RNA. Reverse transcription is necessary for production of HIV's double-stranded DNA, which would be subsequently integrated into the genetic material of the infected cell (where it is called a provirus)



Structure and function of Cytoplasm

Cytoplasm, the semifluid substance of a cell that is external to the nuclear membrane and internal to the cellular membrane. In eukaryotes (i.e., cells having a nucleus), the cytoplasm contains all the organelles with the cell nucleus. The cytoplasm is about 80% water and usually colorless. The main components of the cytoplasm are:

① the mitochondria, which are the sites of energy production through ATP (adenosine triphosphate) synthesis; ② the endoplasmic reticulum, the site of lipid and protein synthesis; ③ the Golgi apparatus, the site where proteins are modified, packaged, and sorted in preparation for transport to their cellular destinations; ④ lysosomes and ⑤ peroxisomes, sacs of digestive enzymes that carry out the intracellular digestion of macromolecules such as lipids and proteins; ⑥ the cytoskeleton, a network of protein fibres that give shape and support to the cell; ⑦ cytosol, the fluid mass that surrounds the various organelles, and ⑧ the nucleus.

Cell organelles

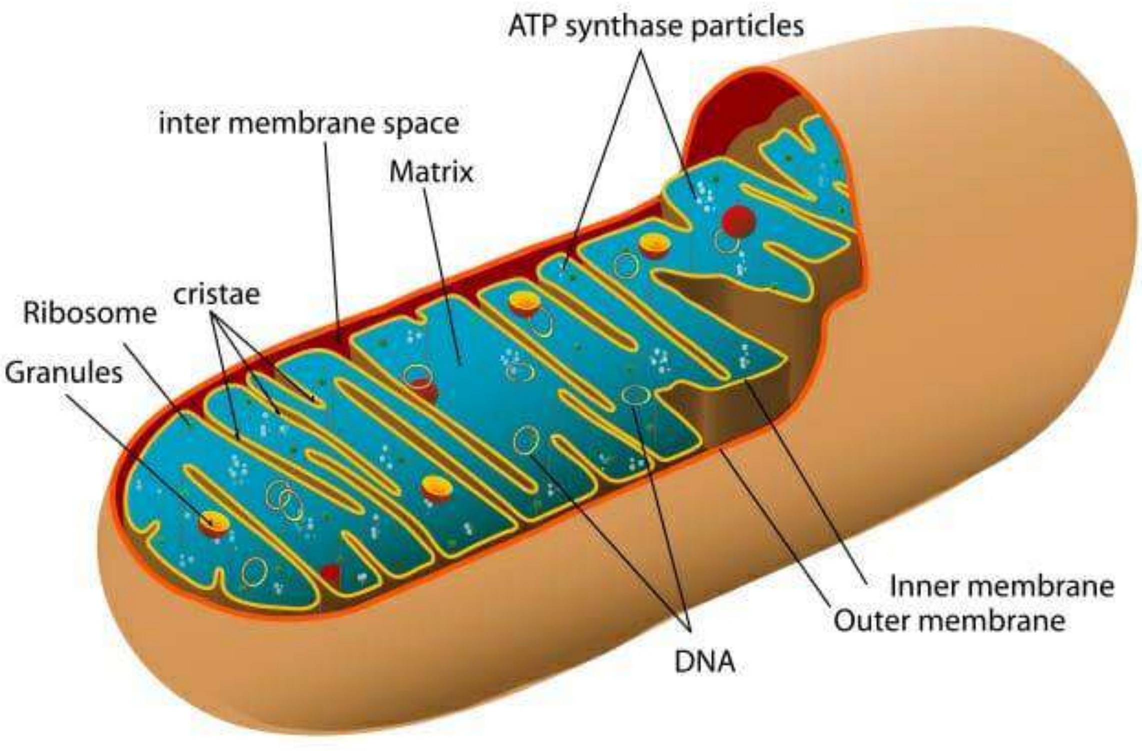
Cell organelles are classified as membranous, that is membrane-bound, and non-membranous.

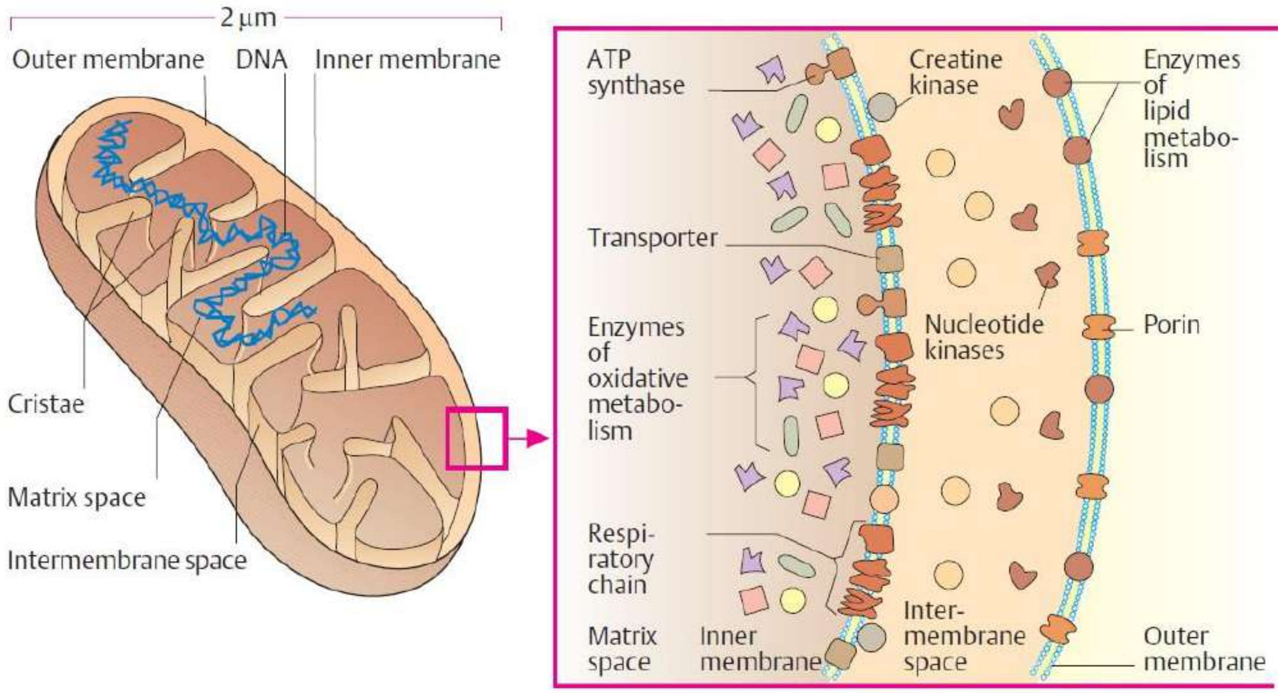
Membranous cell organelles	Non-Membranous cell organelles
• Golgi complex • Endoplasmic reticulum—rough and smooth • Mitochondria • Lysosomes • Peroxisomes • Endosomes	• Ribosomes • Cytoskeleton—microtubules, Microfilaments and intermediate Filaments

1-Mitochondrion Structure

Mitochondria are small membrane-bound organelles that are usually about 1 – 10 microns in length. They can be **spherical** or **rod-shaped**. The mitochondrion is enclosed by two membranes that separate it from the cytosol and the rest of the cell components. The membranes are lipid bilayers with proteins embedded within the layers. The inner membrane is folded to form cristae; this increases the surface area of the membrane and maximizes cellular respiration output. The region between the two membranes is the **intermembrane space.**

Inside the inner membrane is the mitochondrial matrix, and within the matrix there are ribosomes, other enzymes, and mitochondrial DNA. The mitochondrion can reproduce and synthesize proteins independently. It contains the enzymes necessary for transcription, as well as the transfer RNAs and ribosomes required for translation and protein formation.





Mitochondrion Function

Mitochondria are involved in breaking down sugars and fats into energy through aerobic respiration (cellular respiration). This metabolic process creates ATP, the energy source of a cell, through a series of steps that require oxygen. Cellular respiration involves three main stages:

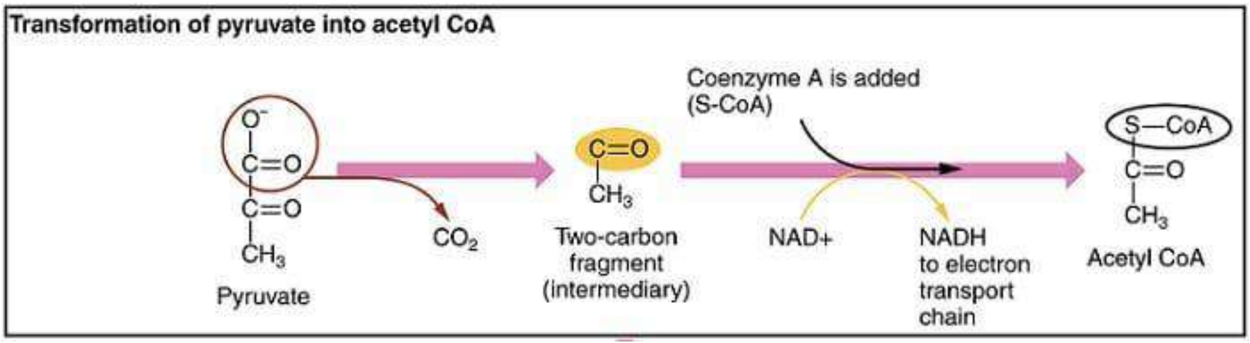
I. Glycolysis

Glycolysis is the process in which one glucose molecule is broken down to form two molecules of pyruvic acid (also called pyruvate). The glycolysis process is a multi-step metabolic pathway that occurs in the cytoplasm of animal cells, plant cells, and the cells of microorganisms. At least six enzymes operate in the metabolic pathway. **Glycolysis** produces **2 ATP**, **2 NADH**, and **2 pyruvate molecule.**

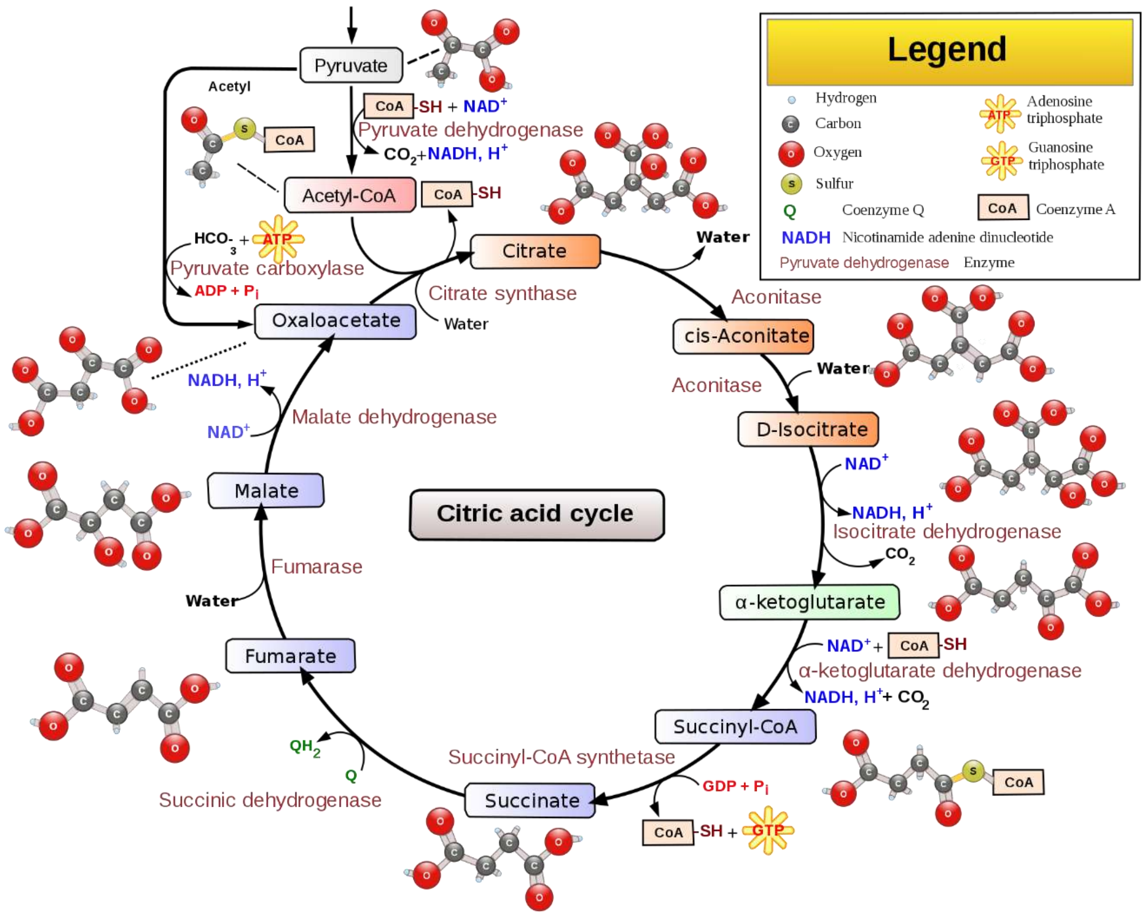
$C_6H_{12}O_6$ + 2 NAD^+ + 2 ATP ---------> 2 pyruvic acid + 2 ATP + 2 NADH + 2 H^+

II. Krebs cycle

In the presence of oxygen, the pyruvate molecules that are produced in glycolysis enter the mitochondrion. The citric acid cycle, or Krebs cycle, occurs in the **mitochondrial matrix**. The citric acid cycle results in the formation of NADH (from NAD^+) which transports electrons to the final stage of cellular respiration. The citric acid cycle produces **two ATP molecules.** Pyruvate enters the mitochondrion and is converted into **acetyl coenzyme A**. This conversion is catalysed by enzymes, produces **NADH**, and releases CO_2. The acetyl group then enters the citric acid cycle, a series of eight enzyme-catalysed steps that begins with citrate and ends in oxaloacetate.



The addition of the acetyl group to oxaloacetate forms citrate and the cycle repeats. The breakdown of citrate into oxaloacetate releases a further two CO_2 molecules and one molecule of ATP (through substrate-level phosphorylation). The majority of the energy is in the reduced coenzymes NADH and $FADH_2$. NAD+ accepts **a hydrogen ion** (H+) and **two electrons** (2e−), while FAD accepts **two hydrogen** ion (H+) and **two electrons** (2e−), as it becomes reduced to NADH + H+. These molecules are then transported to the **electron transport chain**.



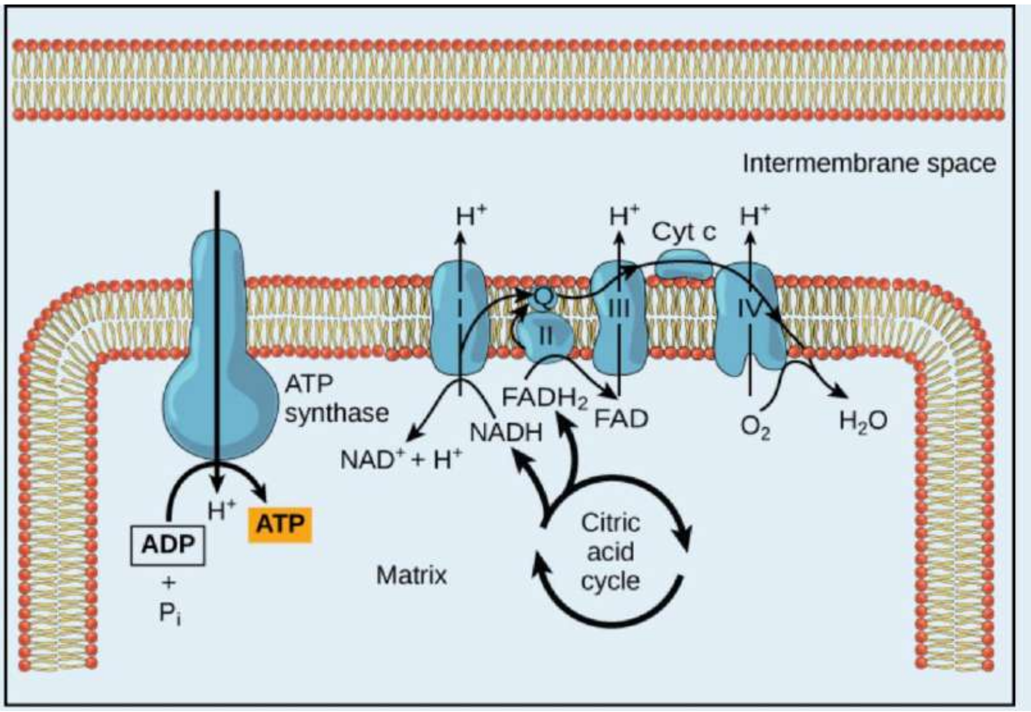
Results of the Krebs Cycle

After the second turn through the Krebs cycle, the original glucose molecule has been broken down completely. All six of its carbon atoms have combined with oxygen to form carbon dioxide. The energy from its chemical bonds has been stored in a total of 16 energy-carrier molecules. These molecules are:

- 4 ATP (including 2 from glycolysis)
- 10 NADH (including 2 from glycolysis)
- 2 $FADH_2$

III. **Oxidative Phosphorylation** or **Electron transport chain.**

Oxidative phosphorylation occurs in the inner membrane of the mitochondrion. The electron transport chain is made up of five multi-protein complexes (I to IV) that are repeated hundreds to thousands of times in the cristae of the inner membrane.



2-Endoplasmic Reticulum

The general structure of the endoplasmic reticulum is a network of membranes called cisternae. These sac-like structures are held together by the cytoskeleton. The phospholipid membrane encloses the cisternal space (or lumen), which is continuous with the perinuclear space but separate from the cytosol.

I. Rough endoplasmic reticulum

The surface of the rough endoplasmic reticulum (often abbreviated RER or Rough ER) is studded with protein-manufacturing ribosomes giving it a "rough" appearance. However, the ribosomes are not a stable part of this organelle's structure as they are constantly being bound and released from the membrane.

The functions of the rough endoplasmic reticulum can be summarized:

1- The synthesis and export of proteins and membrane lipids.
2- Manufacture of lysosomal enzymes with a mannose-6-phosphate marker added in the cis-Golgi network.
3- Integral membrane proteins that stay embedded in the cell membrane.

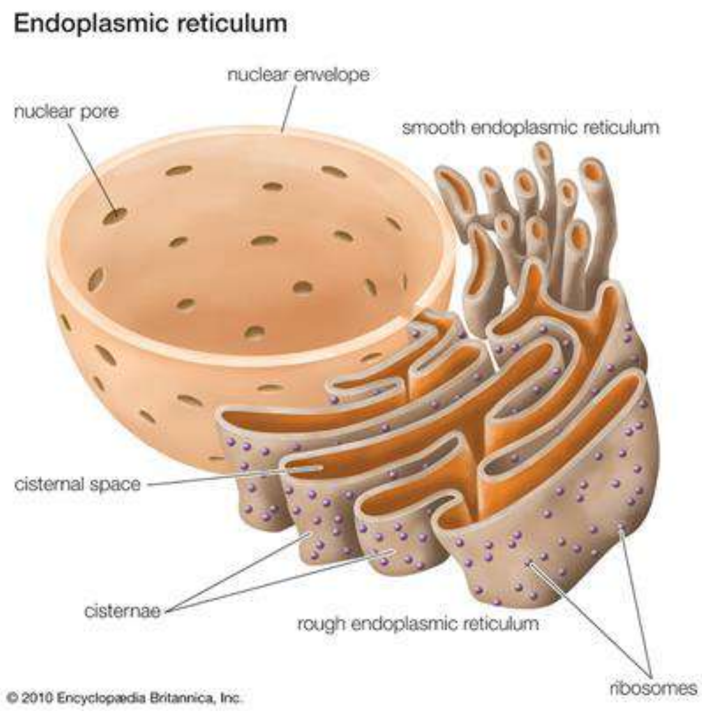
4- Have enzymes that can added carbohydrate chains to protein forming glycoprotein.

II. Smooth endoplasmic reticulum

Smooth endoplasmic reticulum (SER) is an irregular network of folded membranes that are devoid of ribosomes.

The functions of the smooth endoplasmic reticulum can be summarized:

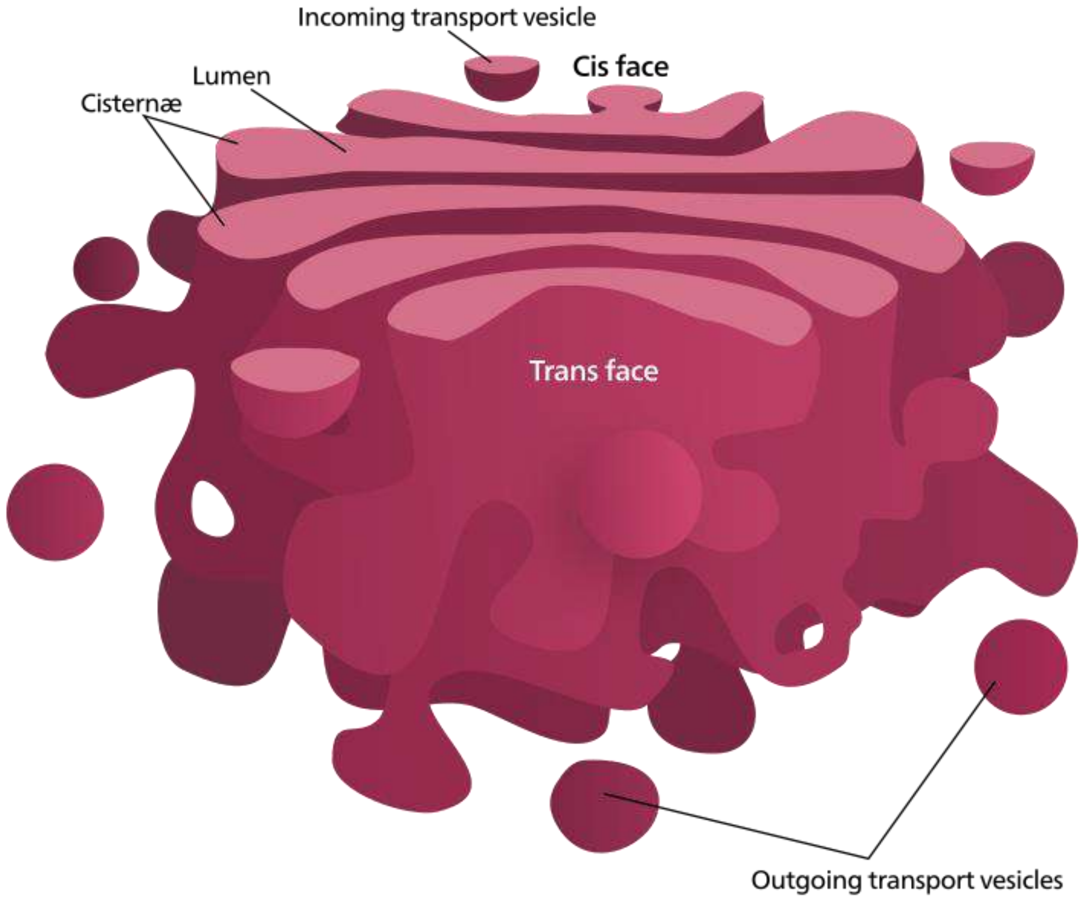
1- The smooth ER is important in the synthesis of lipids, such as cholesterol and phospholipids, which form all the membranes of the cell.
2- In addition, it is important for the synthesis and secretion of steroid hormones from cholesterol and other lipid precursors.
3- In addition, it is involved in carbohydrate metabolism. For instance, the final reaction of gluconeogenesis occurs in the lumen of the smooth ER since it contains the enzyme glucose-6-phosphatase.
4- They are also abundant in liver cells and help in detoxification of drugs.



Golgi apparatus

The Golgi apparatus, also known as the Golgi complex, Golgi body, or simply the Golgi, is an organelle found in most eukaryotic cells. Part of the endomembrane system in the cytoplasm, the Golgi apparatus packages proteins into membrane-bound vesicles inside the cell before the vesicles are sent to their destination.

Proteins synthesized in the ER are packaged into vesicles, which then fuse with the Golgi apparatus. These cargo proteins are modified and destined for secretion via exocytosis or for use in the cell. The Golgi body can be thought of as similar to a post office: it packages and labels items which it then sends to different parts of the cell or to the extracellular space.



3-Cytoskeleton

Cytoskeleton, a system of filaments or fibres that is present in the cytoplasm of eukaryotic cells. The cytoskeleton organizes other constituent of the cell, maintains the cell's shape, and is responsible for the locomotion of the cell itself and the movement of the various organelles within it. It is a complex, dynamic network of interlinking protein filaments that extends from the cell nucleus to the cell membrane. The cytoskeletal matrix is a dynamic structure composed of three main proteins, which are capable of rapid growth or disassembly dependent on the cell's requirements.

The three main structural components of the cytoskeleton are **microtubules** (formed by tubulins), **microfilaments** (formed by actins) and **intermediate filaments**. All three components interact with each other non-covalently

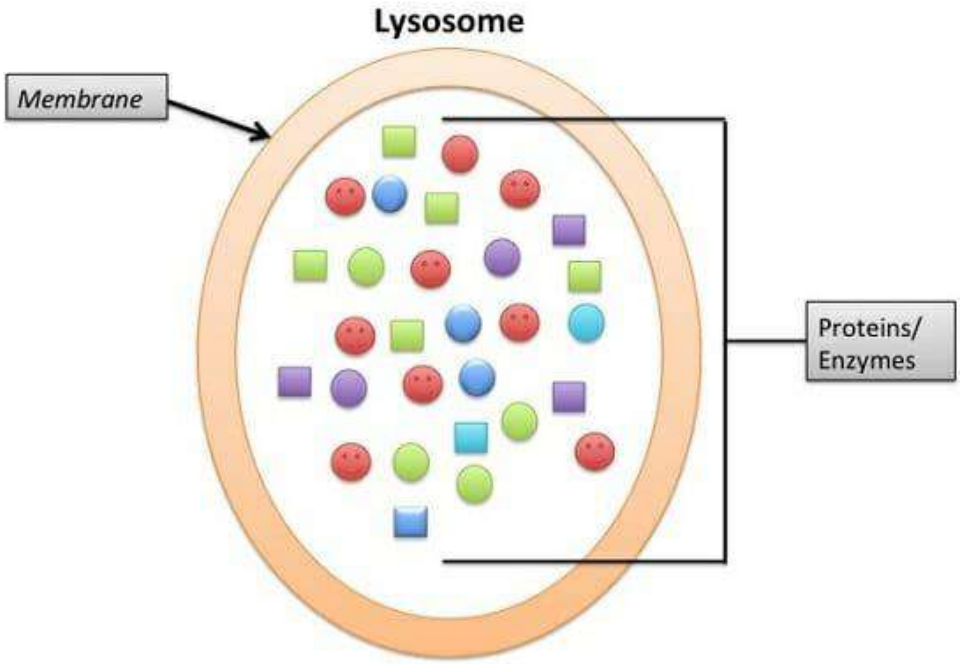
Functions:

Microtubules help in maintenance of cell shape, intracellular transport and formation of mitotic spindles during mitosis.

5. Lysosomes

Lysosomes act as the waste disposal system of the cell by digesting obsolete or un-used materials in the cytoplasm, from both inside and outside the cell. Material (complex molecules such as carbohydrates, lipids, proteins, and nucleic acids) from outside the cell is taken-up through endocytosis, while material from the inside of the cell is digested through autophagy. Lysosomes are known to contain more than 60 different enzymes, and have more than 50 membrane proteins. Enzymes of the lysosomes are synthesised in the rough endoplasmic reticulum.

Synthesis of lysosomal enzymes is controlled by nuclear genes. Mutations in the genes for these enzymes are responsible for more than 30 different human genetic disorders, which are collectively known as lysosomal storage diseases. These diseases result from an accumulation of specific substrates, due to the inability to break them down. These genetic defects are related to several neurodegenerative disorders, cancers, cardiovascular diseases, and aging-related diseases.

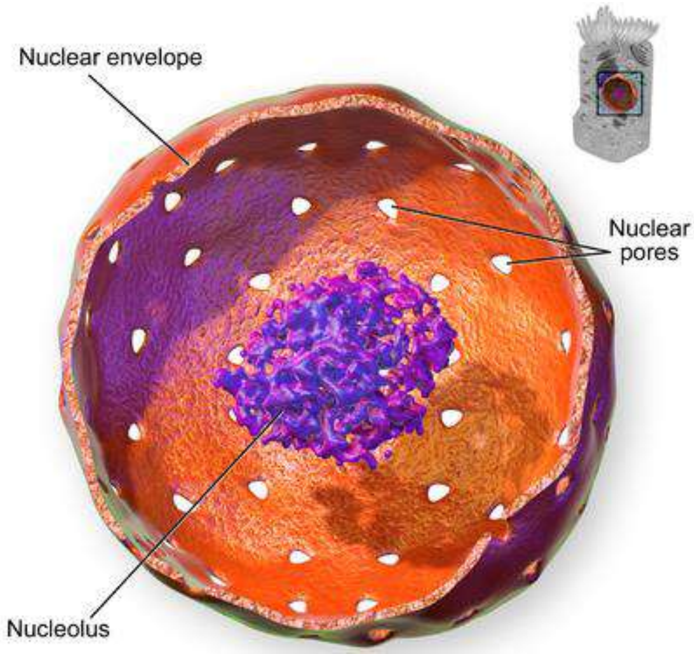


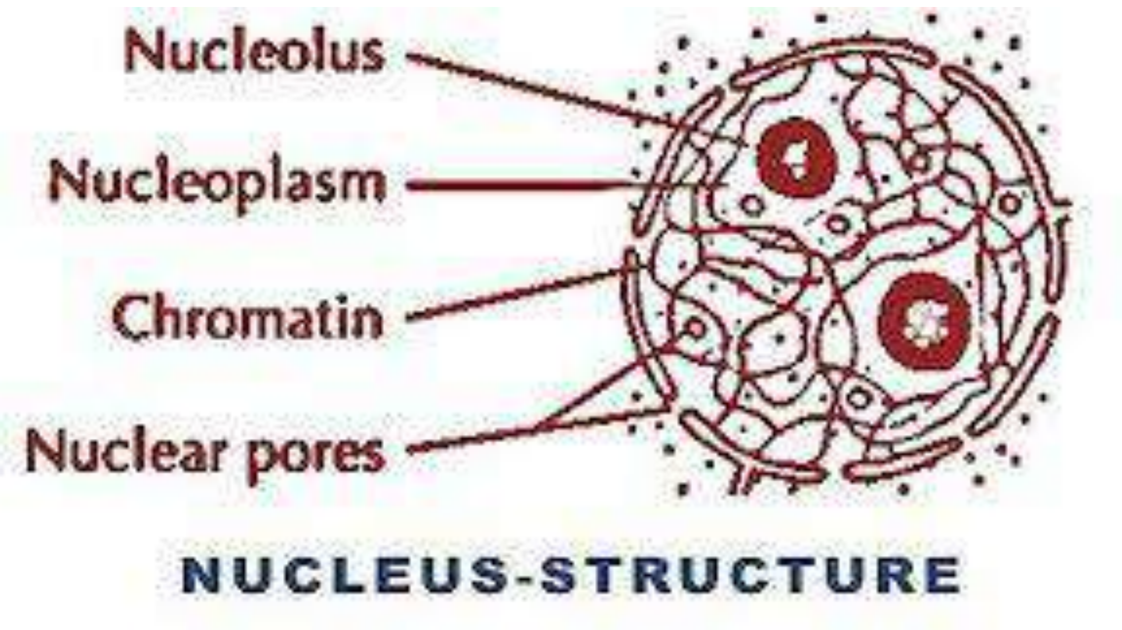
6. Nucleus

The nucleus is a membrane-bound organelle that contains genetic material (DNA) of eukaryotic organisms. As such, it serves to maintain the integrity of the cell by facilitating transcription and replication processes. It's the largest organelle inside the cell taking up about a tenth of the entire cell volume. This makes it one of the easiest organelles to identify under the microscope. Some eukaryotic cells lack a nucleus and are referred to as enucleate cells (e.g. erythrocytes) while others may have more than one nucleus (e.g. slime moulds).

Function

The nucleus provides a site for genetic transcription that is segregated from the location of translation in the cytoplasm, allowing levels of gene regulation that are not available to prokaryotes. The main function of the cell nucleus is to control gene expression and mediate the replication of DNA during the cell cycle.



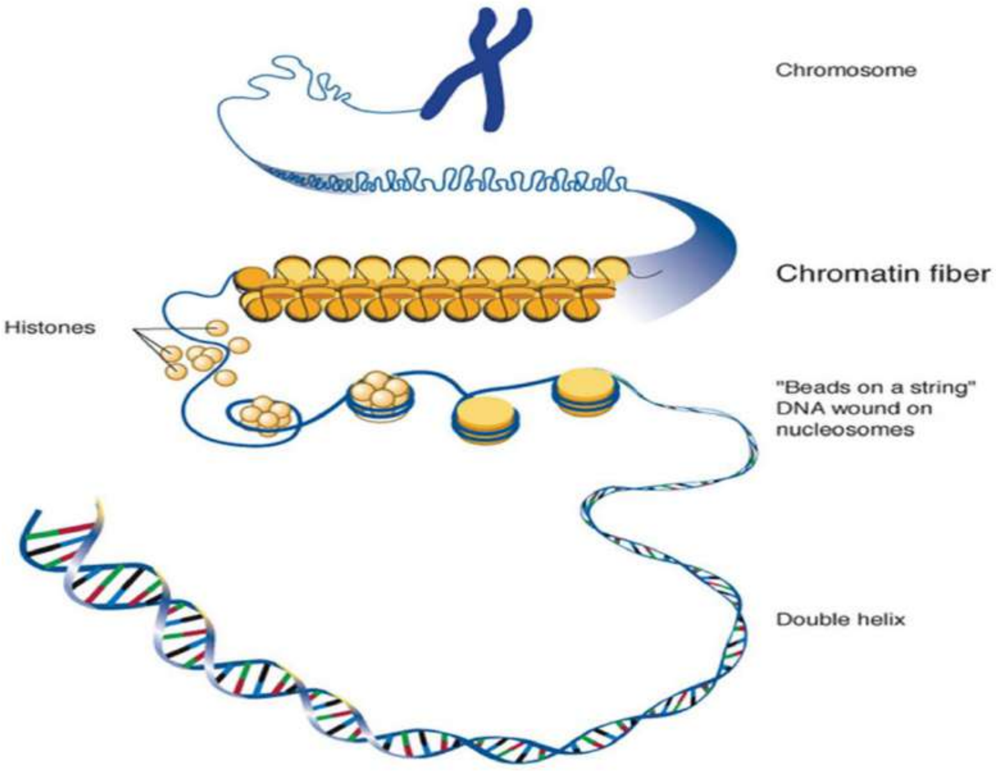


Chromatin

Chromatin is a complex of macromolecules found in cells, consisting of DNA, protein, and RNA. The primary functions of chromatin are (1) to package DNA into a more compact, denser shape, (2) to reinforce the DNA macromolecule to allow mitosis. (3) to prevent DNA damage, and (4) to control gene expression and DNA replication.

Chromosomes

● A chromosome consists of a highly folded and condensed single DNA molecule. The associated proteins help in organization of the DNA.
● Chromosomes are best seen during cell division when they reach maximum condensation.
● Each chromosome consists of a short arm (p) and a long arm (q); they are connected to each other by a constricted region known as centromere.
● After DNA replication, chromosomes consist of a pair of identical chromatids joined by a centromere.



Nucleus chemical composition:

- 9-12 percent DNA
- 15 percent histone
- 65 percent enzymes, neutral proteins and acid proteins
- 5 percent RNA
- 3 percent lipids

Some of the main functions of the nucleus include:

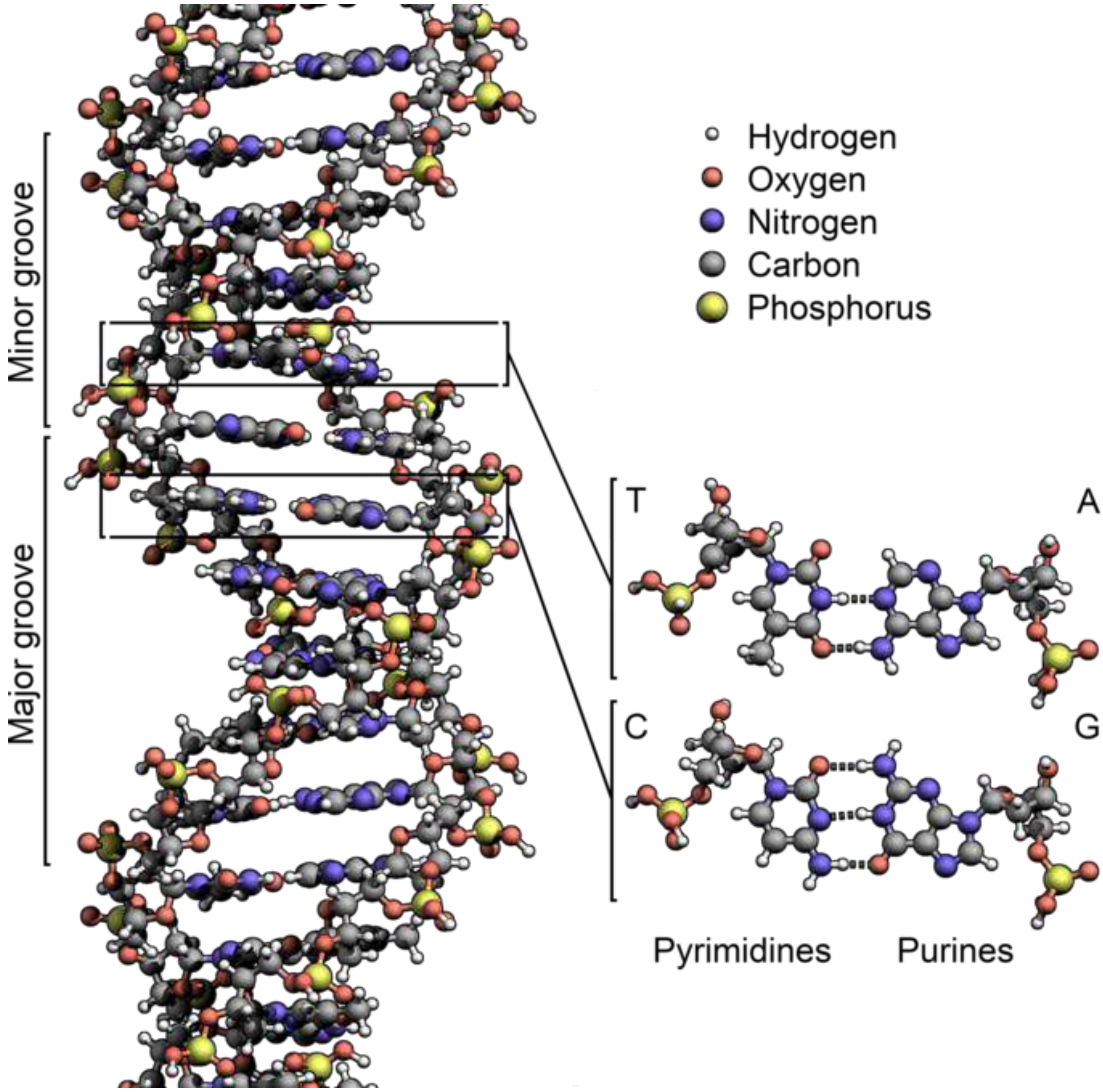
- Protein synthesis, cell division, and differentiation
- Control the synthesis of enzymes involved in cellular metabolism
- Controlling hereditary traits of the organism
- Store DNA strands, proteins, and RNA
- Site of RNA transcription - e.g. mRNA required for protein synthesis

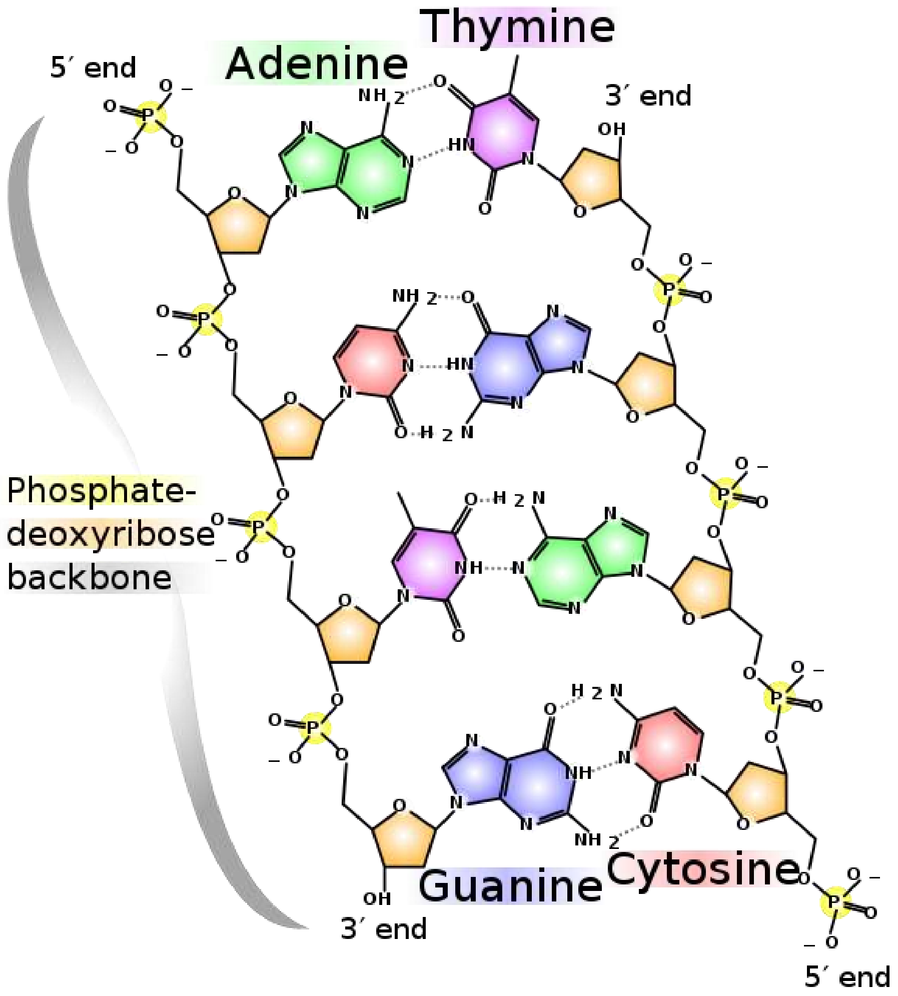
Deoxyribonucleic acid (DNA)

Deoxyribonucleic acid (DNA) is a molecule composed of two chains that coil around each other to form a double helix carrying genetic instructions for the development, functioning, growth and reproduction of all know organisms and many viruses. DNA and ribonucleic acid (RNA) are nucleic acids; alongside proteins, lipids and complex carbohydrates (polysaccharides), nucleic acids are one of the four major types of macromolecules that are essential for all known forms of life.

The two DNA strands are also known as polynucleotides as they are composed of simpler monomeric units called nucleotides. Each nucleotide is composed of one of four nitrogen- containing nucleobases (cytosine [C], guanine [G], adenine [A] or thymine [T]), a sugar called deoxyribose, and a phosphate group. The nucleotides are joined to one another in a chain by covalent bonds between the sugar of one nucleotide and the phosphate of the next, resulting in an alternating sugar-phosphate backbone.

The nitrogenous bases of the two separate polynucleotide strands are bound together, according to base pairing rules (A with T and C with G), with hydrogen bonds to make double-stranded DNA. The complementary nitrogenous bases are divided into two groups, pyrimidines and purines. In DNA, the pyrimidines are thymine and cytosine; the purines are adenine and guanine.

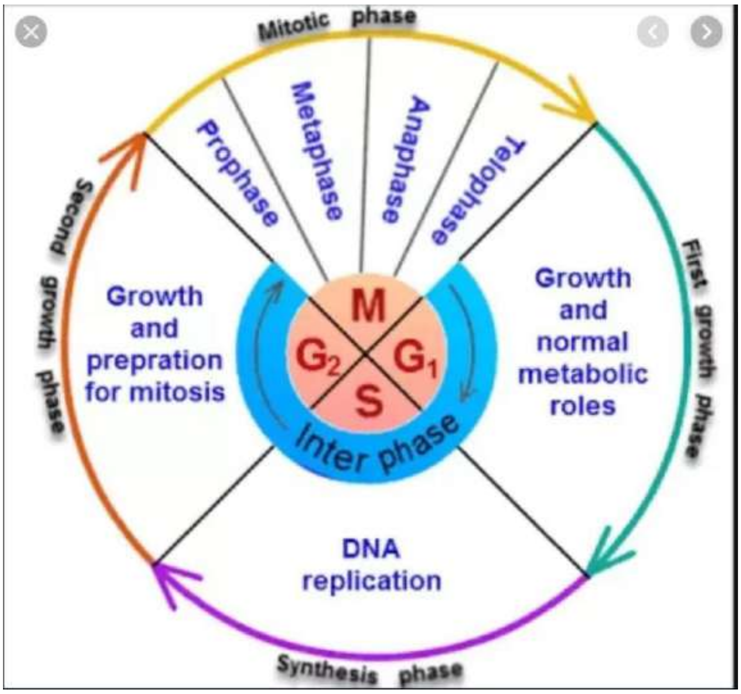




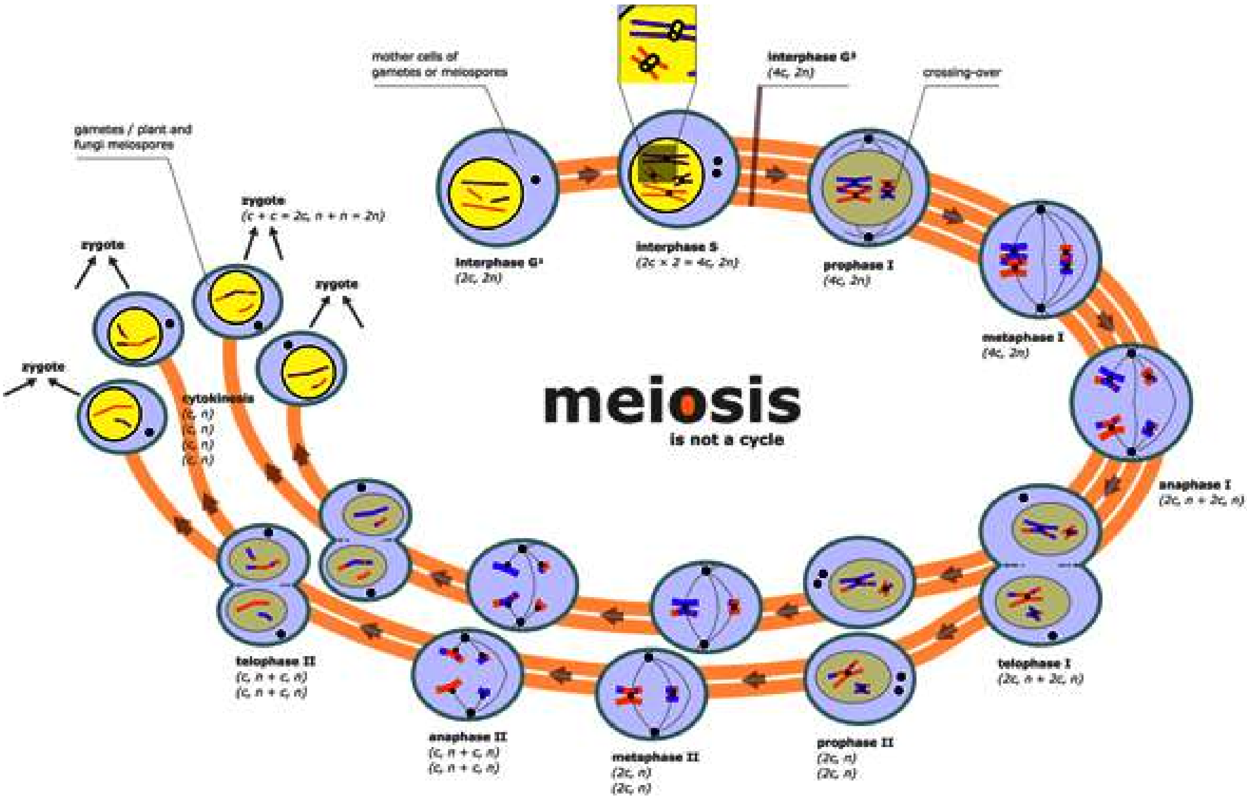
How do cells divide?

There are two types of cell division: mitosis and meiosis. Most of the time when people refer to “cell division,” they mean mitosis, the process of making new body cells. Meiosis is the type of cell division that creates egg and sperm cells.

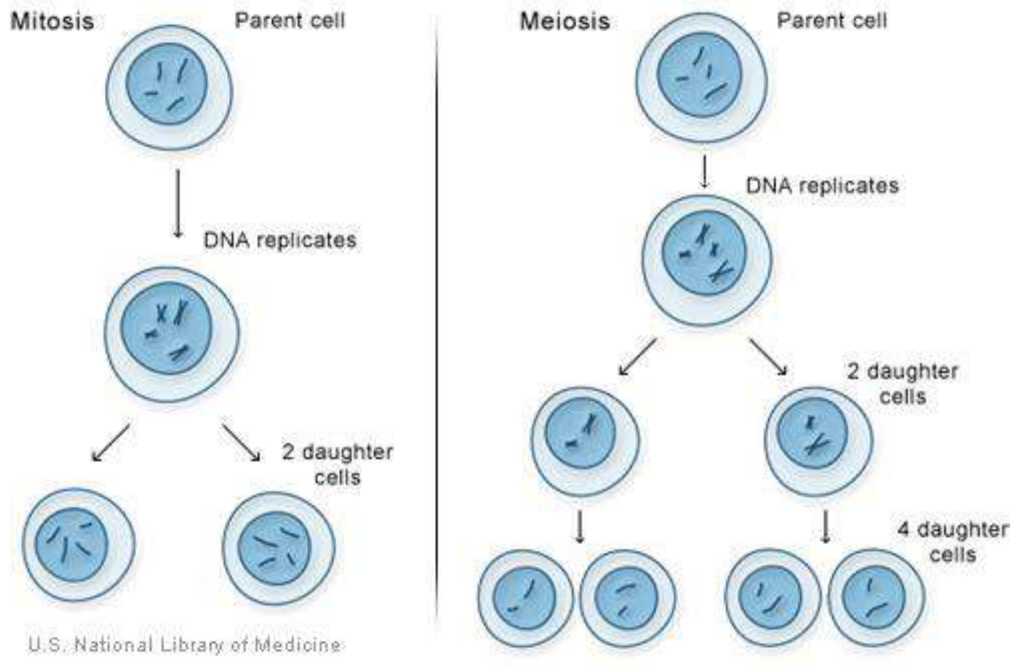
Mitosis is a fundamental process for life. During mitosis, a cell duplicates all of its contents, including its chromosomes, and splits to form two identical daughter cells. Because this process is so critical, the steps of mitosis are carefully controlled by a number of genes. When mitosis is not regulated correctly, health problems such as cancer can result.



The other type of cell division, meiosis, ensures that humans have the same number of chromosomes in each generation. It is a two-step process that reduces the chromosome number by half—from 46 to 23—to form sperm and egg cells. When the sperm and egg cells unite at conception, each contributes 23 chromosomes so the resulting embryo will have the usual 46. Meiosis also allows genetic variation through a process of DNA shuffling while the cells are dividing.



Mitosis and meiosis, the two types of cell division.



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Fifth Edition R o b e r t F. We a v e r University of Kansas

Introduction to Viruses

A virus is a submicroscopic infectious agent (small parasite) that cannot reproduce by itself. All viruses are obligatory replicates only inside the living cells of an organism. Also viruses can infect all types of life forms, from animals and plants to microorganisms, including bacteria and archaea. When infected by a virus, a host cell is forced to produce many thousands of identical copies of the original virus.

A **virus** Viruses may be defined as **acellular organisms** whose **genomes** consist of **nucleic acid**, and which obligatory **replicate inside host cells** using **host metabolic machinery** and **ribosomes** to form a **pool of components** which assemble into particles called **VIRIONS**, which serve to **protect the genome** and to **transfer it to other cells**. When infected by a virus, a host cell is forced to produce many thousands of identical copies of the original virus. Unlike most living things, viruses do not have cells that divide; new viruses are assembled in the infected host cell. But unlike still simpler infectious agents, viruses contain genes, which gives them the ability to mutate and evolve. Over 5,000 species of viruses have been discovered yet.

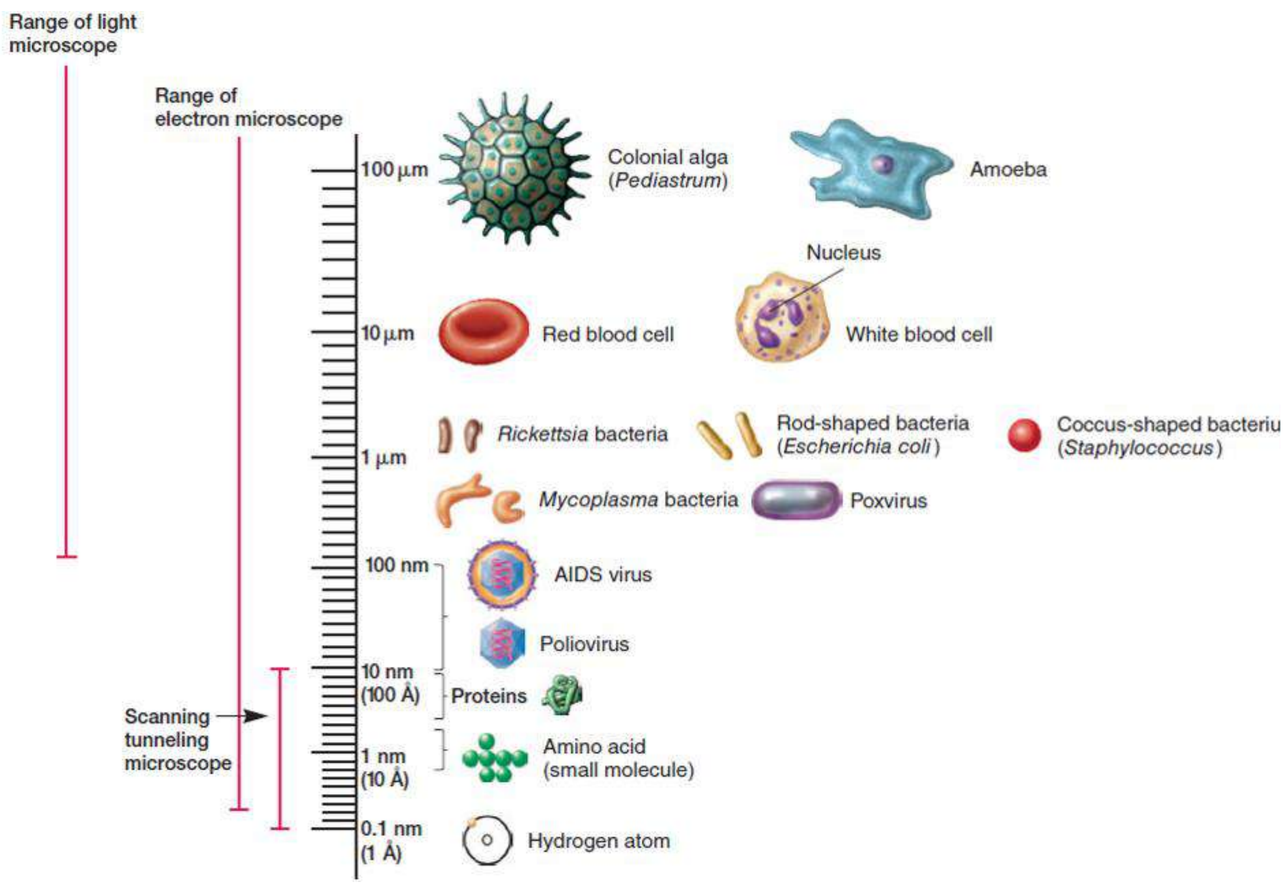
Most viruses have either RNA or DNA as their genetic material. The nucleic acid may be single- or double-stranded of genetic material. The entire infectious virus particle, called a virion, consists of the nucleic acid and an outer shell of protein. The simplest viruses contain only enough RNA or DNA to encode four proteins. The most complex can encode 100 – 200 proteins.

Viral infections can cause disease in humans, animals and even plants. Antibiotics have no effect on viruses, but antiviral drugs have been developed to treat life-threatening infections. Vaccines that produce lifelong immunity can prevent some viral infections.

Viruses reproduce rapidly because they have only a few genes compared to humans who have 20,000–25,000. For example, influenza virus has only eight genes and rotavirus has eleven. These genes encode structural proteins that form the virus particle, or non-structural proteins, that are only found in cells infected by the virus.

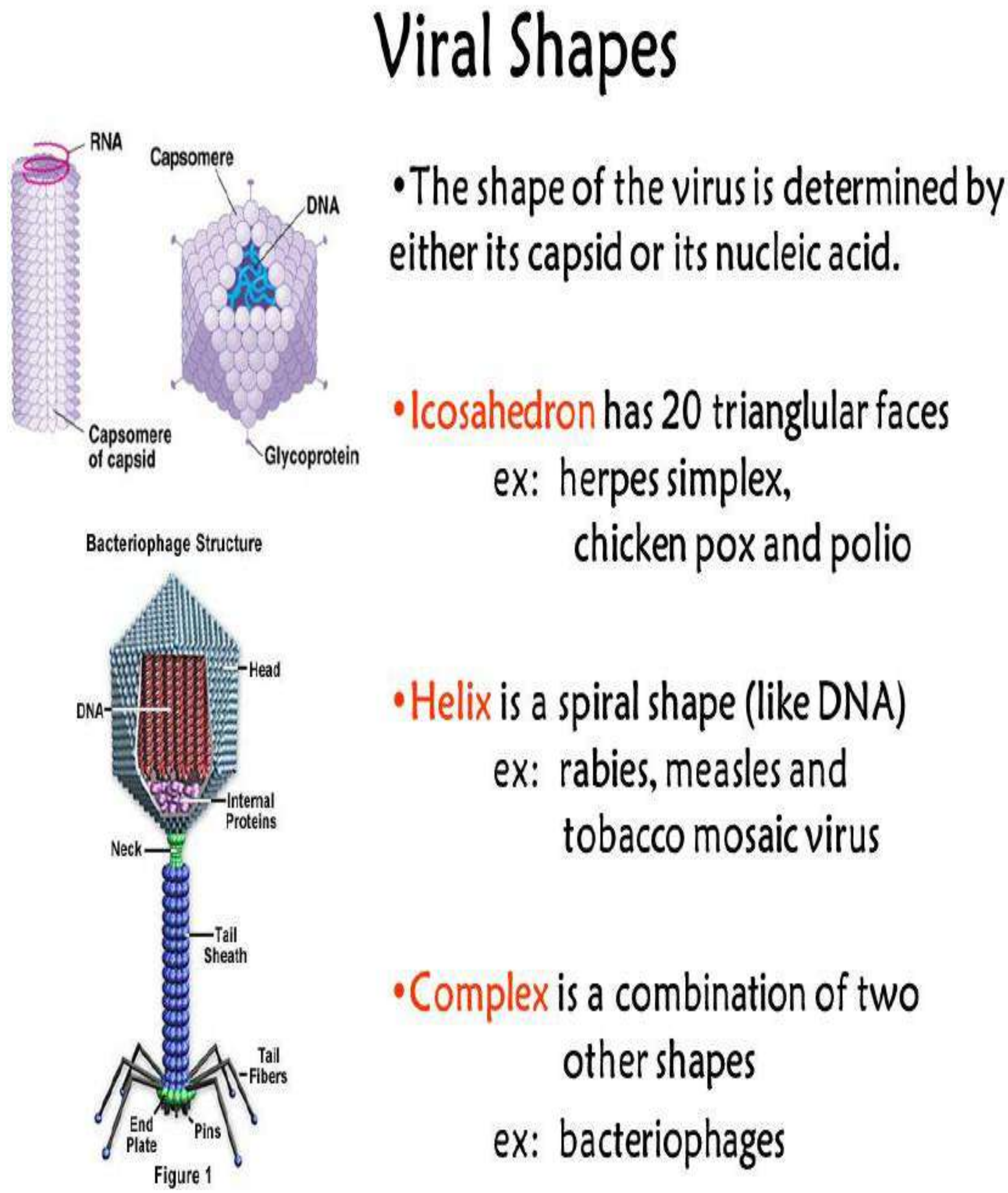
Size of Viruses

A small virus has a diameter of about 20 nm. ***Parvovirus***. A large virus has a diameter of up to 400 nm. ***Poxviruses***. Viruses are among the smallest infectious agents, and most of them can only be seen by electron microscopy. Most viruses cannot be seen by light microscopy, their sizes range from 20 to 300 nm.



Shape of Viruses: -

Viruses vary in shape from the simple helical and icosahedral to more complex structures. A virus consists of two or three parts: genome and capsid or genome, capsid and envelope



Structure of virus

A virus particle, also known as a virion, (infectious unit) consists of genes made from DNA or RNA which are surrounded by a protective coat of protein called a capsid (nucleic **acid genome and protein capsid called nucleocapsid**). Some viruses are surrounded by a bubble of lipid (fat) called an envelope.

1-Genome: - Most viruses have either RNA or DNA as their genetic material. The nucleic acid may be single- or double-stranded. David Baltimore proposed that viruses be classified according to the nature of their genome and the relationship between the genome and the viral mRNA.

The Baltimore classification of viruses is based on the mechanism of mRNA production. Viruses must generate mRNAs from their genomes to produce proteins and replicate themselves, but different mechanisms are used to achieve this in each virus family. Viral genomes may be single-stranded (ss) or double-stranded (ds), RNA or DNA, and may or may not use reverse transcriptase (RT). In addition, ssRNA viruses may be either sense (+) or antisense (−). This classification places viruses into seven groups:

I: dsDNA viruses (e.g. Adenoviruses, Herpesviruses, Poxviruses)

II: ssDNA viruses (+ strand or "sense") DNA (e.g. Parvoviruses)

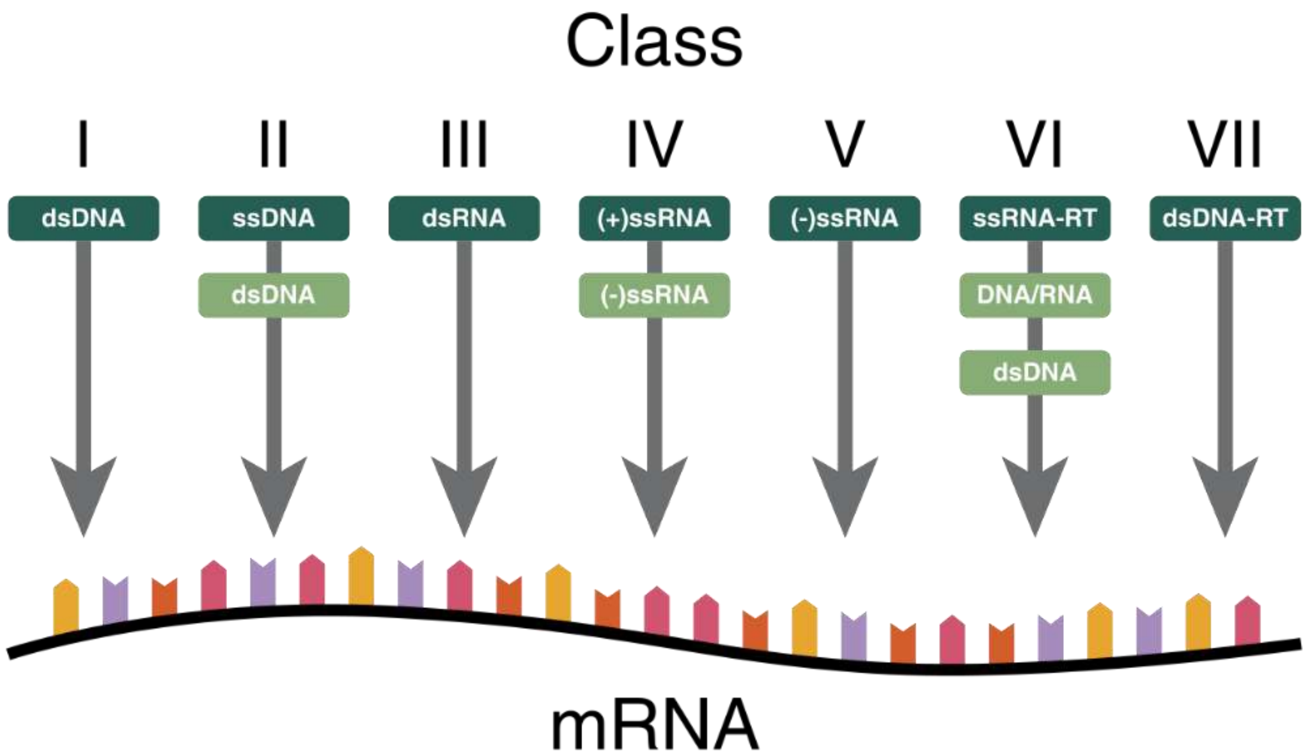
III: dsRNA viruses (e.g. Reoviruses)

IV: (+) ssRNA viruses (+ strand or sense) RNA (Coronaviruses, Picoronaviruses, Togavrises)

V: (−) ssRNA viruses (− strand or antisense) RNA (e.g. Orthomyxoviruses, Rhabdoviruses)

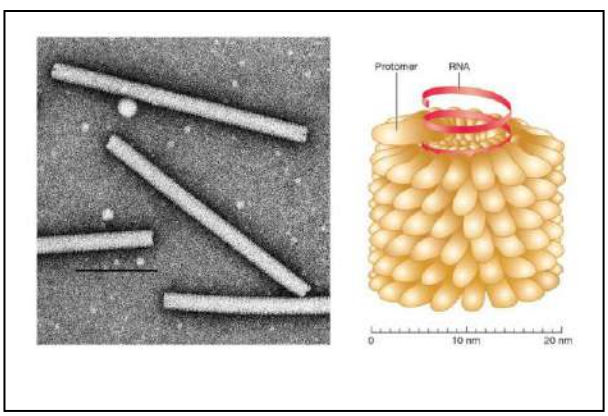
VI: ssRNA-RT viruses (+ strand or sense) RNA with DNA intermediate in life-cycle (e.g. Retroviruses)

VII: dsDNA-RT viruses DNA with RNA intermediate in life cycle (e.g. Hepadnaviruses)

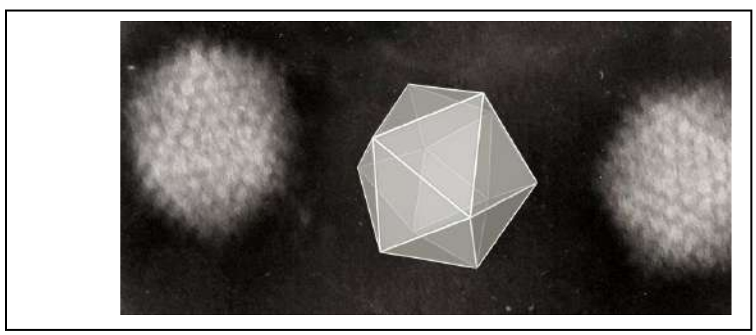


2- Protein capsid (**nucleocapsid**) :-The protein shell, or coat, that encloses the nucleic acid genome. A capsid is almost always made up of repeating structural subunits that are arranged in one of two symmetrical structures, a **helix** or an **icosahedron.** The functions of protein capsid are **a-** Protect the viral nucleic acid, **b-** Participate in the viral infection, and **c-** Share the antigenicity.

A



B

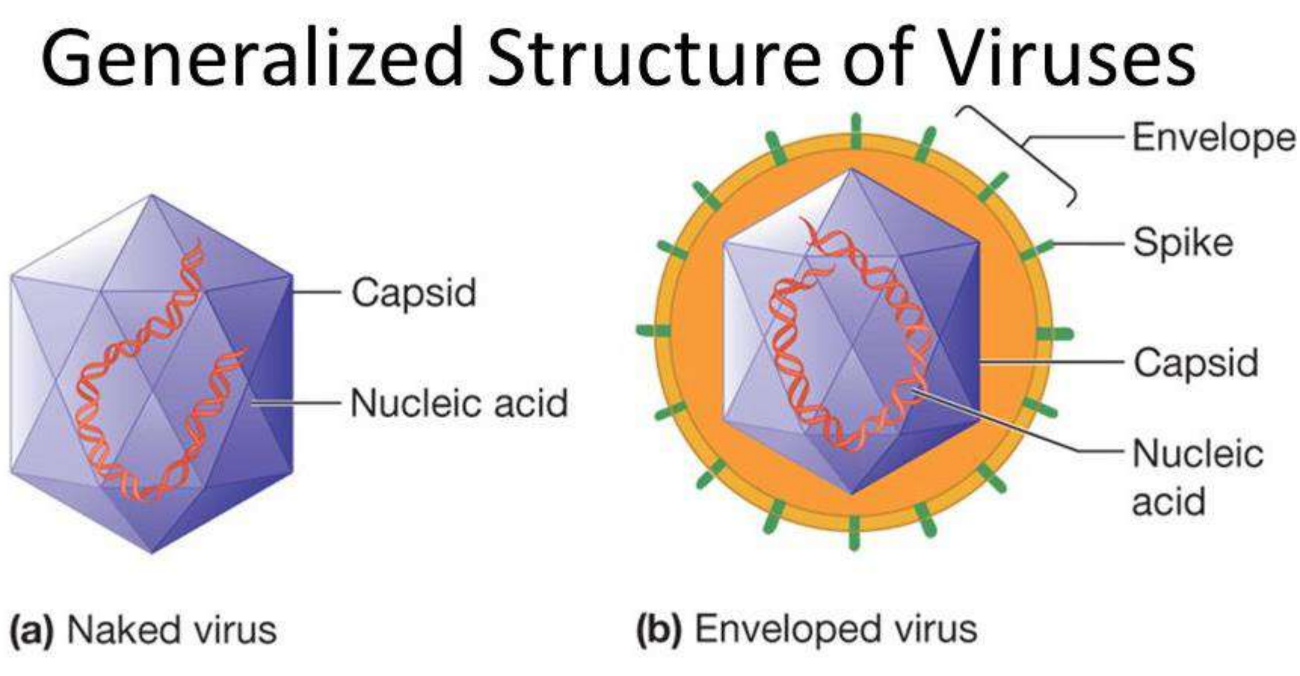


A- The helical structure of the virus rod.

B- Structure of icosahedral adenovirus. Electron micrograph with an illustration to show shape

3-Viral Envelope: In some animal viruses, the nucleocapsid is surrounded by a membrane, called an envelope, made up of a lipid bilayer, and is **comprised of host-cell lipids.** It also contains **virally encoded proteins**, often **glycoproteins** which are trans-membrane proteins. These viral proteins serve many purposes, such as *binding to receptors on the host cell, *playing a role in membrane fusion and cell entry, etc.

Enveloped viruses are formed by **budding** through cellular membranes, usually the **plasma membrane** but sometimes an internal membrane such as the **ER, Golgi,** or nucleus. In these cases, the assembly of viral components (genome, capsid, matrix) occurs on the inside face of the membrane. This ability to bud allows the virus to exit the host cell without lysing or killing the host. In contrast, **non-enveloped** viruses, and some enveloped viruses, **kill** the host cell in order to escape.



Viruses spread in many ways.

1-Viruses influenza are spread through the ***air*** by droplets of moisture when people cough or sneeze.

2- Viruses such as Hepatitis A virus are transmitted by the ***fecal–oral route***, which involves the contamination of hands, food and water.

3- Rotavirus is often spread by ***direct contact*** with infected children.

4-The human immunodeficiency virus, HIV, is transmitted by bodily fluids transferred ***during sex***.

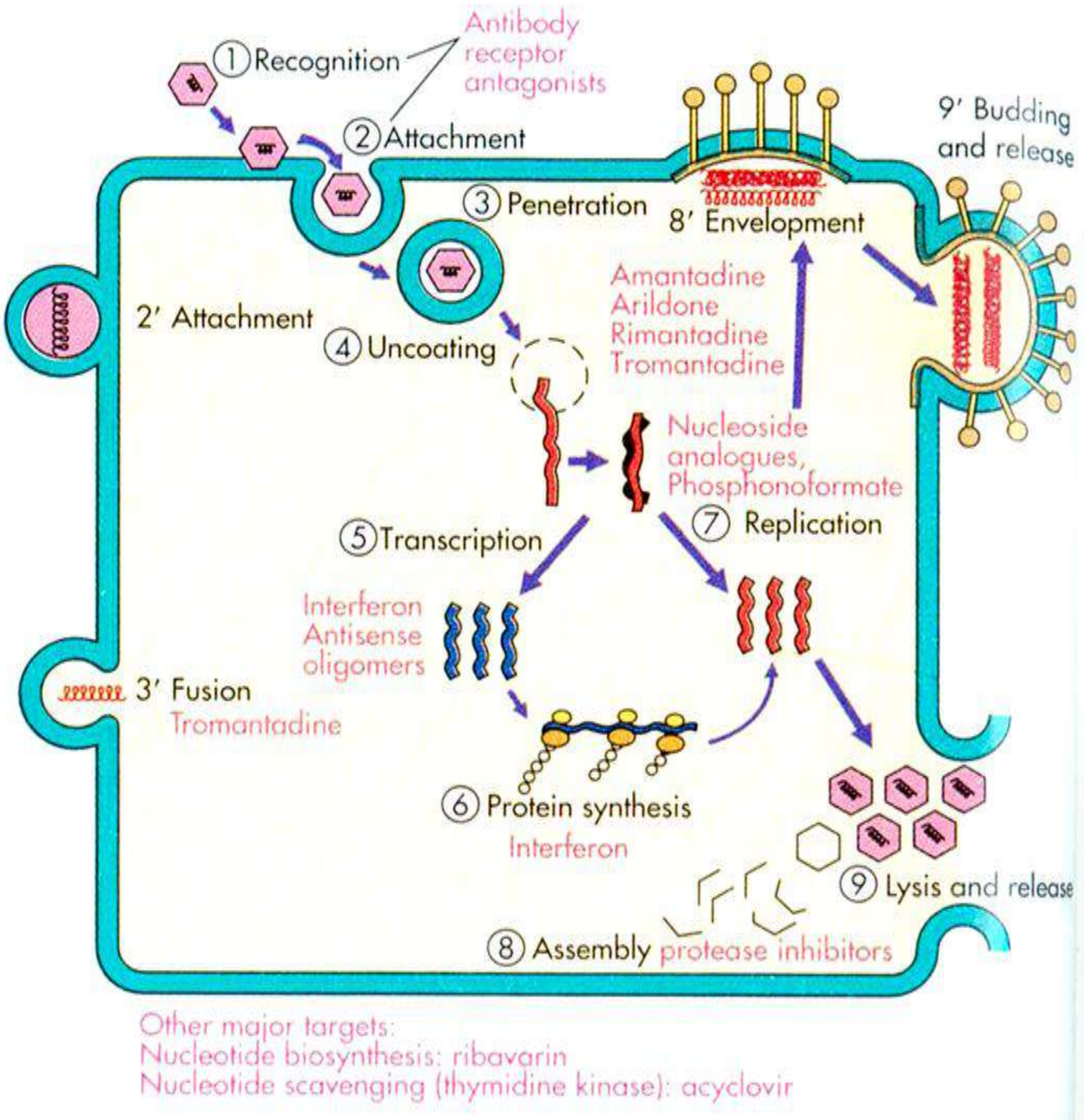
5- Dengue virus, are spread by ***blood-sucking insects***.

- **Lifecycle of Viruses**

As obligate intracellular parasites, Virus must enter and replicate in living cells in order to “reproduce” themselves. This “growth cycle” involves specific attachment of virus, penetration and un-coating, nucleic acid transcription, protein synthesis, maturation and assembly of the virions and their subsequent release from the cell by budding or lysis

There are six basics, overlapping stages in the life cycle of viruses in living cell.

- **Attachment** is the binding of the virus to specific molecules on the surface of the cell.
- **Penetration** follows attachment; viruses penetrate the host cell by endocytosis or by fusion with the cell. Virions are either engulfed into vacuoles by “endocytosis” or the virus envelope fuses with the plasma membrane to facilitate entry
- **Uncoating** happens inside the cell when the viral capsid is removed and destroyed by viral enzymes or host enzymes, thereby exposing the viral nucleic acid.
- **Replication** of virus particles is the stage where a cell uses viral messenger RNA in its protein synthesis systems to produce viral proteins. The RNA or DNA synthesis abilities of the cell produce the virus's DNA or RNA.
- **Assembly** takes place in the cell when the newly created viral proteins and nucleic acid combine to form hundreds of new virus particles.
- **Release** occurs when the new viruses escape or are released from the cell. Most viruses achieve this by making the cells burst, a process called lysis. Other viruses such as HIV are released more gently by a process called budding.



① Recognition
Antibody
receptor
antagonists
② Attachment
③ Penetration
8′ Envelopment
9′ Budding
and release
2′ Attachment
④ Uncoating
Amantadine
Arildone
Rimantadine
Tromantadine
Nucleoside
analogues,
Phosphonoformate
⑤ Transcription
⑦ Replication
Interferon
Antisense
oligomers
3′ Fusion
Tromantadine
⑥ Protein synthesis
Interferon
⑨ Lysis and release
⑧ Assembly protease inhibitors
Other major targets:
Nucleotide biosynthesis: ribavarin
Nucleotide scavenging (thymidine kinase): acyclovir

- **Anti-viral targeting**

Antiviral drugs are medicines that decrease the ability of flu viruses to reproduce. The general idea behind modern antiviral drug design is to identify viral proteins, or parts of proteins, that can be disabled. For example, a researcher might target a critical enzyme synthesized by the virus, but not by the patient, that is common across strains, and see what can be done to interfere with its operation.

1- Inhibitors of attachment fusion and uncoating:

Fusion inhibitor: A class of antiretroviral drugs that work on the outside of the host CD4 cell to prevent Human Immunodeficiency Virus (HIV) from fusing with and infecting it. Fusion inhibitors act by binding to an envelope protein and blocking the structural changes necessary for the virus to fuse with the host CD4 cell.

This stage of viral replication can be inhibited in two ways:

1. Using agents which mimic the virus-associated protein (VAP) and bind to the cellular receptors. This may include VAP anti-idiotypic antibodies, natural ligands of the receptor and anti-receptor antibodies.
2. Using agents which mimic the cellular receptor and bind to the VAP. This includes anti-VAP antibodies, receptor anti-idiotypic antibodies, extraneous receptor and synthetic receptor mimics.

2. Inhibitors of nucleic acid synthesis:

Ribavirin is an analog of the nucleoside guanosine; its action varies for different viruses. This drug alters cellular nucleotide pools, inhibits viral RNA synthesis, and may cause

lethal RNA mutations.

3. Protease inhibitors:

They inhibit the action of viruses protease; used in combination with AZT and a second nucleoside analog as “cocktail” therapy for HIV.

4. Neuraminidase inhibitors:

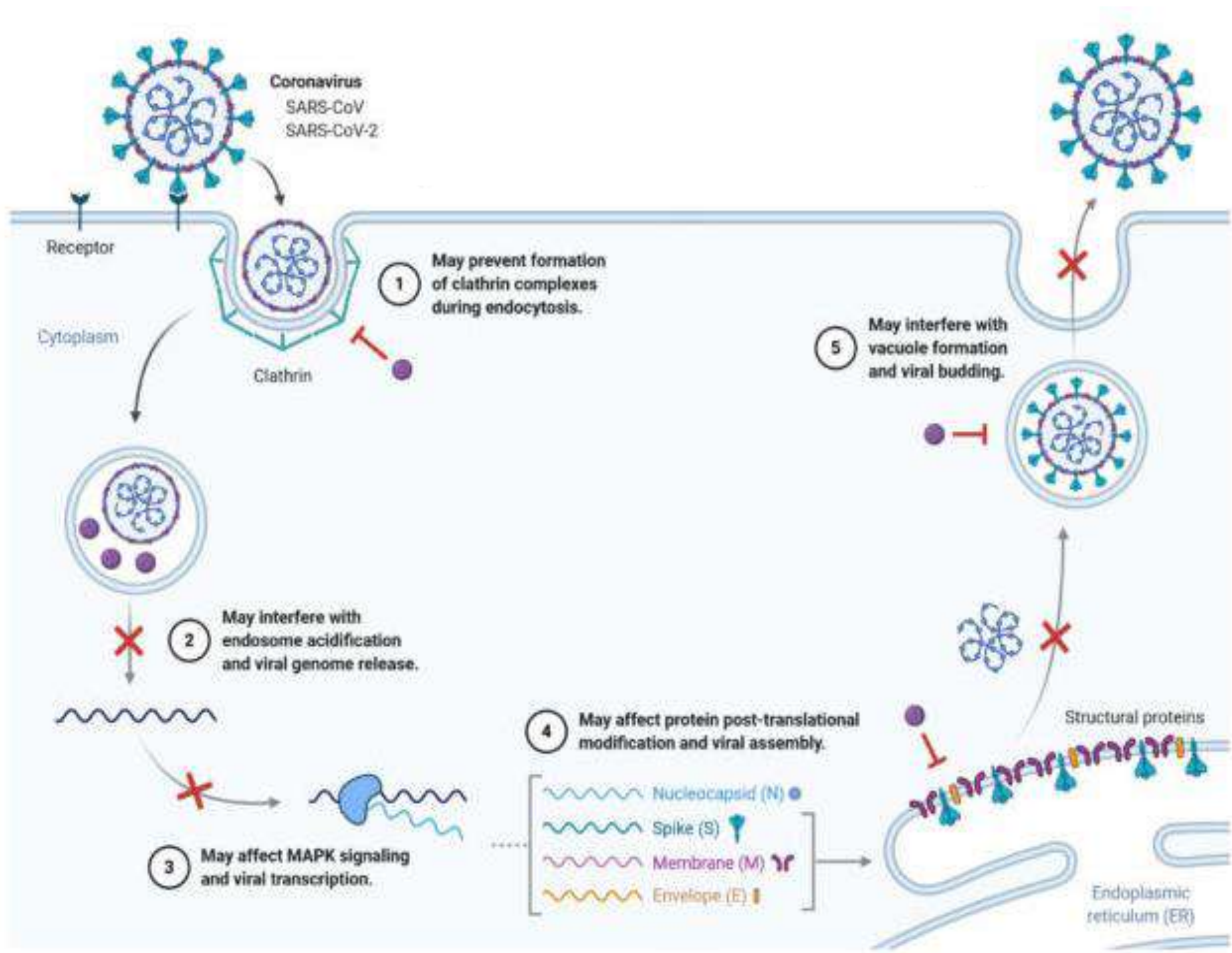
a. These drugs include oseltamivir and zanamivir.

b. They inhibit the neuraminidase of influenza A and B viruses; they may be used for prophylaxis as well as treatment.

5. mRNA inhibitors:

a. Fomivirsen is a synthetic oligonucleotide complementary to a sequence in CMV RNA (an antisense compound). It prevents transcription of early CMV genes.

b. It is approved for intravitreal therapy of CMV retinitis after other therapies have failed.



Structure and function of Cytoplasm

Cytoplasm, the semifluid substance of a cell that is external to the nuclear membrane and internal to the cellular membrane. In eukaryotes (i.e., cells having a nucleus), the cytoplasm contains all the organelles with the cell nucleus. The cytoplasm is about 80% water and usually colorless. The main components of the cytoplasm are:

① the mitochondria, which are the sites of energy production through ATP (adenosine triphosphate) synthesis; ② the endoplasmic reticulum, the site of lipid and protein synthesis; ③ the Golgi apparatus, the site where proteins are modified, packaged, and sorted in preparation for transport to their cellular destinations; ④ lysosomes and ⑤ peroxisomes, sacs of digestive enzymes that carry out the intracellular digestion of macromolecules such as lipids and proteins; ⑥ the cytoskeleton, a network of protein fibres that give shape and support to the cell; ⑦ cytosol, the fluid mass that surrounds the various organelles, and ⑧ the nucleus.

Cell organelles

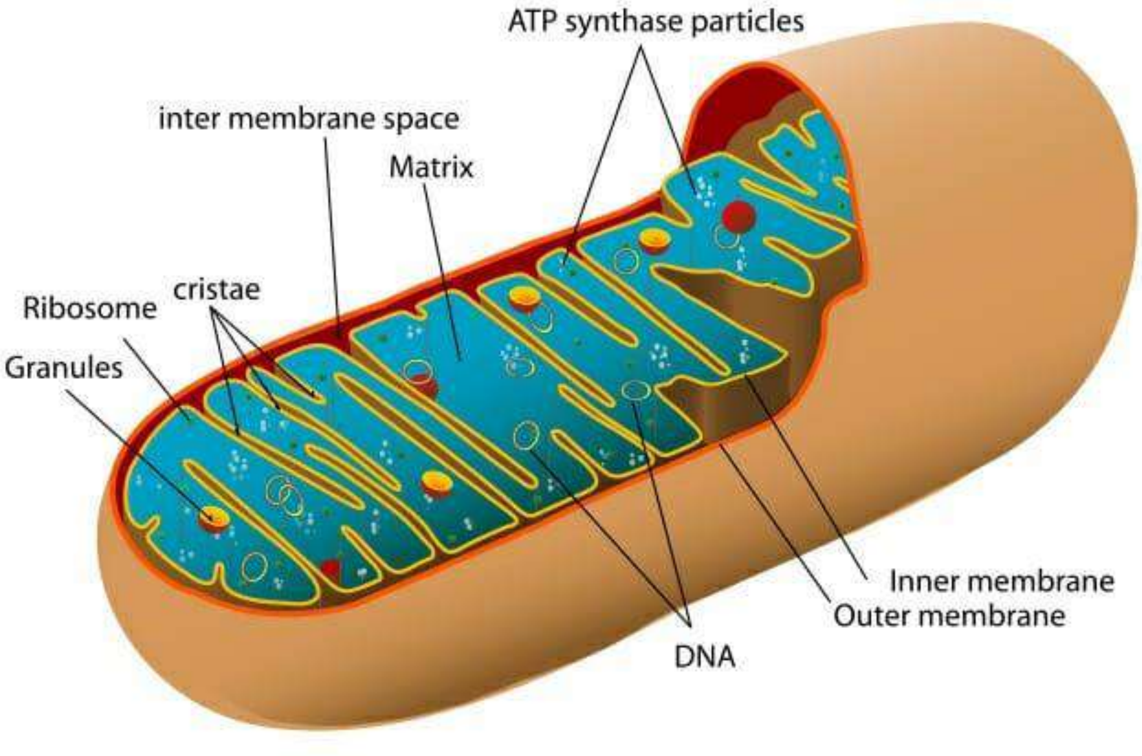
Cell organelles are classified as membranous, that is membrane-bound, and non-membranous.

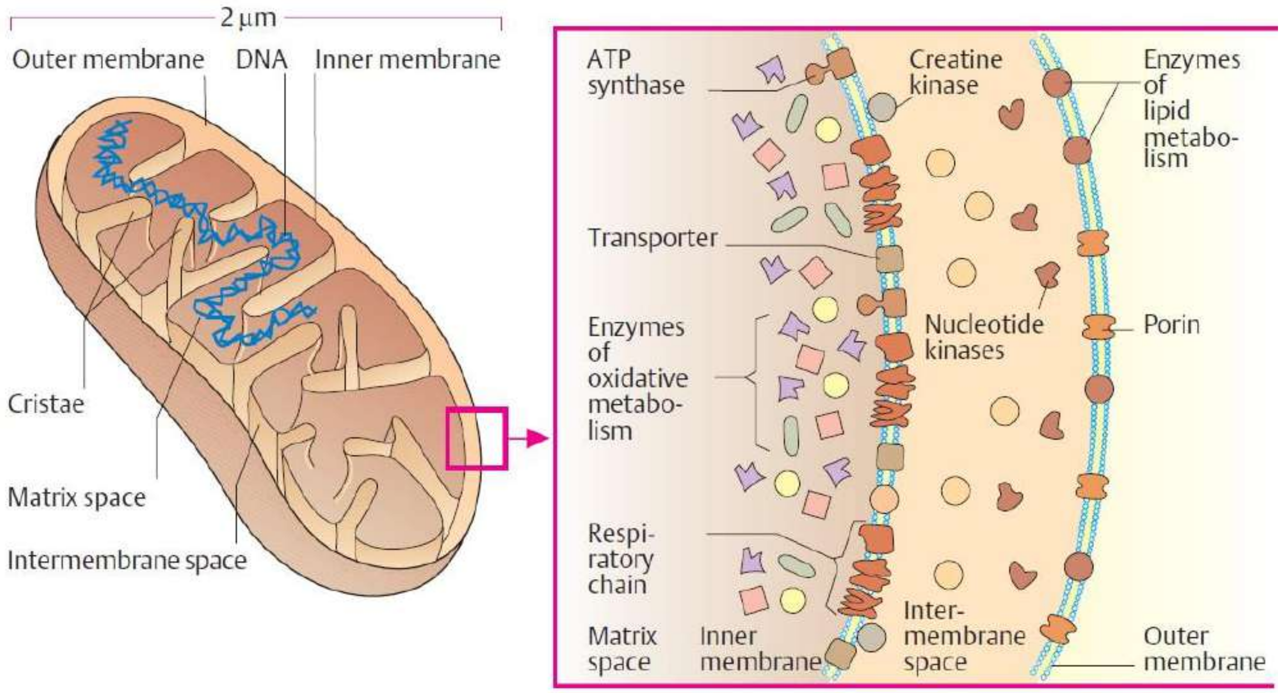
Membranous cell organelles	Non-Membranous cell organelles
• Golgi complex • Endoplasmic reticulum—rough and smooth • Mitochondria • Lysosomes • Peroxisomes • Endosomes	• Ribosomes • Cytoskeleton—microtubules, Microfilaments and intermediate Filaments

1-Mitochondrion Structure

Mitochondria are small membrane-bound organelles that are usually about 1 – 10 microns in length. They can be **spherical** or **rod-shaped**. The mitochondrion is enclosed by two membranes that separate it from the cytosol and the rest of the cell components. The membranes are lipid bilayers with proteins embedded within the layers. The inner membrane is folded to form cristae; this increases the surface area of the membrane and maximizes cellular respiration output. The region between the two membranes is the **intermembrane space.**

Inside the inner membrane is the mitochondrial matrix, and within the matrix there are ribosomes, other enzymes, and mitochondrial DNA. The mitochondrion can reproduce and synthesize proteins independently. It contains the enzymes necessary for transcription, as well as the transfer RNAs and ribosomes required for translation and protein formation.





Mitochondrion Function

Mitochondria are involved in breaking down sugars and fats into energy through aerobic respiration (cellular respiration). This metabolic process creates ATP, the energy source of a cell, through a series of steps that require oxygen. Cellular respiration involves three main stages:

I. Glycolysis

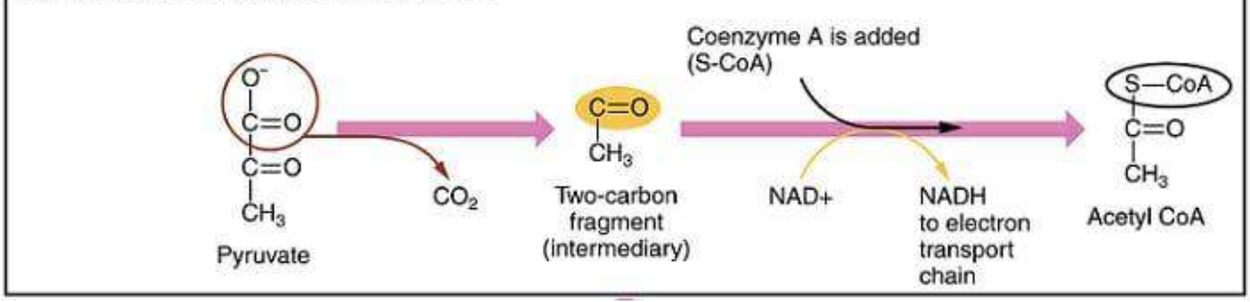
Glycolysis is the process in which one glucose molecule is broken down to form two molecules of pyruvic acid (also called pyruvate). The glycolysis process is a multi-step metabolic pathway that occurs in the cytoplasm of animal cells, plant cells, and the cells of microorganisms. At least six enzymes operate in the metabolic pathway. **Glycolysis** produces **2 ATP**, **2 NADH**, and **2 pyruvate molecule.**

$C_6H_{12}O_6$ + 2 NAD^+ + 2 ATP ---------> 2 pyruvic acid + 2 ATP + 2 NADH + 2 H^+

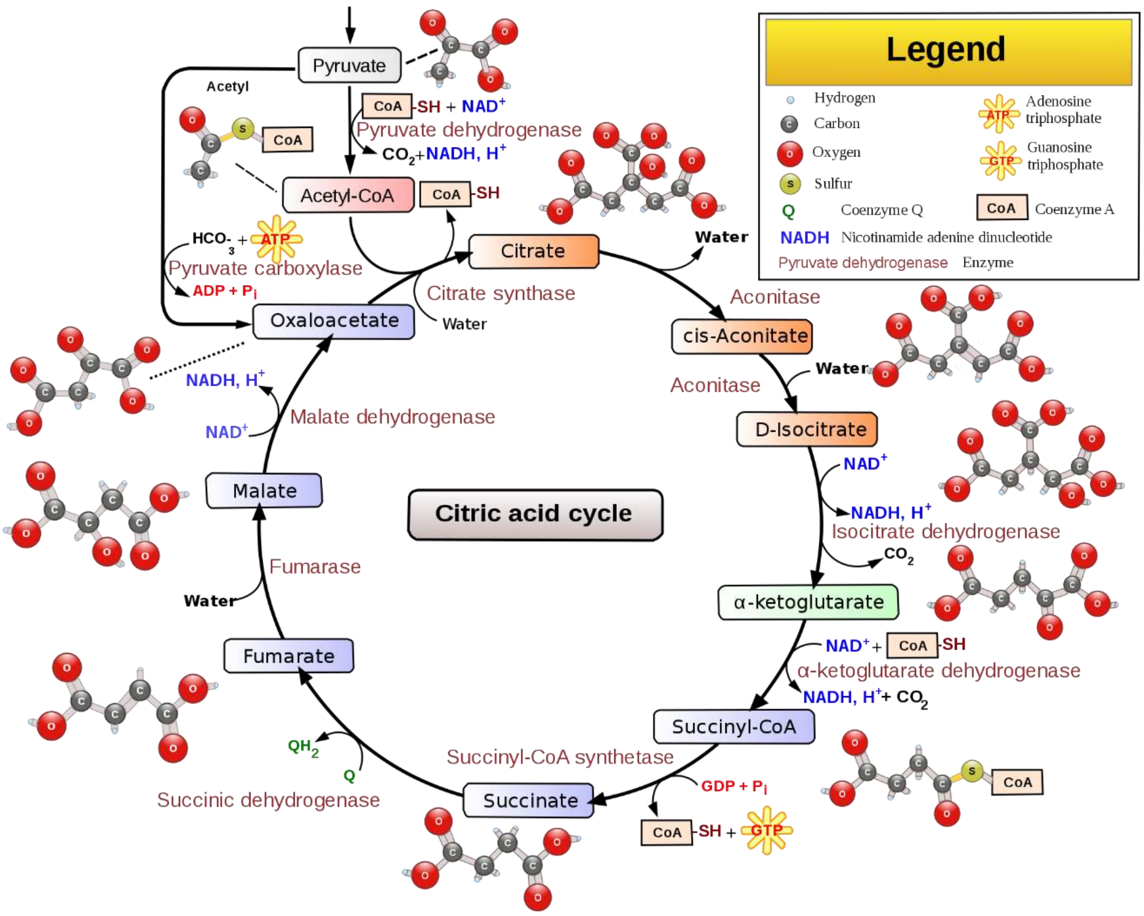
II. **Krebs cycle**

In the presence of oxygen, the pyruvate molecules that are produced in glycolysis enter the mitochondrion. The citric acid cycle, or Krebs cycle, occurs in the **mitochondrial matrix**. The citric acid cycle results in the formation of NADH (from NAD^+) which transports electrons to the final stage of cellular respiration. The citric acid cycle produces **two ATP molecules.** Pyruvate enters the mitochondrion and is converted into **acetyl coenzyme A**. This conversion is catalysed by enzymes, produces **NADH**, and releases CO_2. The acetyl group then enters the citric acid cycle, a series of eight enzyme-catalysed steps that begins with citrate and ends in oxaloacetate.

Transformation of pyruvate into acetyl CoA



The addition of the acetyl group to oxaloacetate forms citrate and the cycle repeats. The breakdown of citrate into oxaloacetate releases a further two CO_2 molecules and one molecule of ATP (through substrate-level phosphorylation). The majority of the energy is in the reduced coenzymes NADH and $FADH_2$. NAD+ accepts **a hydrogen ion** (H+) and **two electrons** (2e−), while FAD accepts **two hydrogen** ion (H+) and **two electrons** (2e−), as it becomes reduced to NADH + H+. These molecules are then transported to the **electron transport chain**.



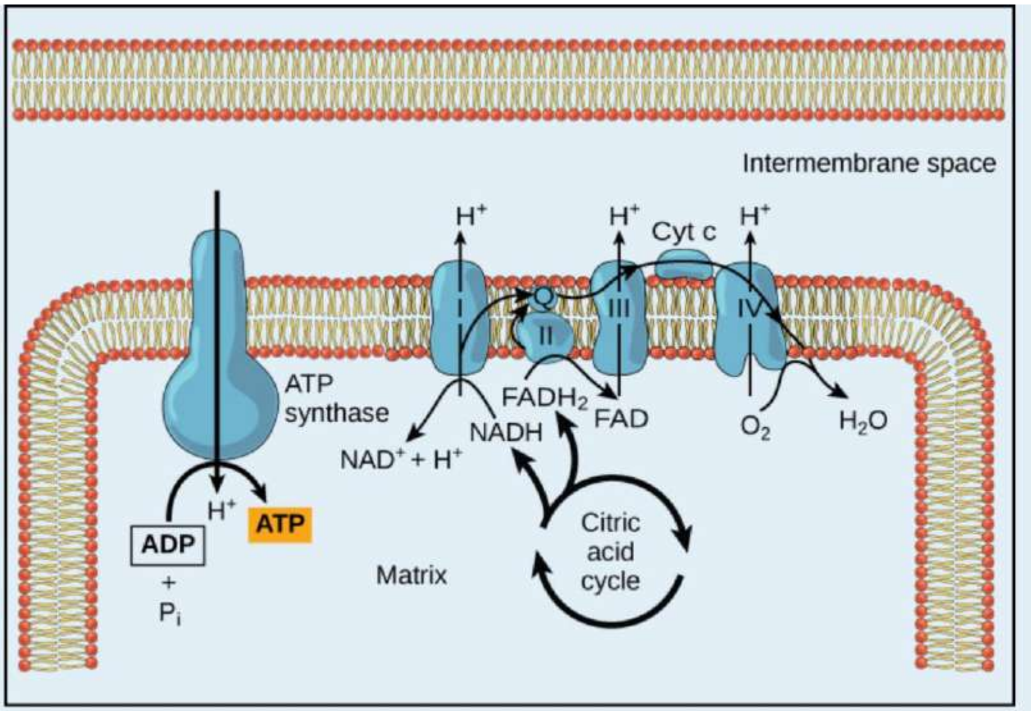
Results of the Krebs Cycle

After the second turn through the Krebs cycle, the original glucose molecule has been broken down completely. All six of its carbon atoms have combined with oxygen to form carbon dioxide. The energy from its chemical bonds has been stored in a total of 16 energy-carrier molecules. These molecules are:

- 4 ATP (including 2 from glycolysis)
- 10 NADH (including 2 from glycolysis)
- 2 $FADH_2$

III. **Oxidative Phosphorylation** or **Electron transport chain.**

Oxidative phosphorylation occurs in the inner membrane of the mitochondrion. The electron transport chain is made up of five multi-protein complexes (I to IV) that are repeated hundreds to thousands of times in the cristae of the inner membrane.



2-Endoplasmic Reticulum

The general structure of the endoplasmic reticulum is a network of membranes called cisternae. These sac-like structures are held together by the cytoskeleton. The phospholipid membrane encloses the cisternal space (or lumen), which is continuous with the perinuclear space but separate from the cytosol.

I. Rough endoplasmic reticulum

The surface of the rough endoplasmic reticulum (often abbreviated RER or Rough ER) is studded with protein-manufacturing ribosomes giving it a "rough" appearance. However, the ribosomes are not a stable part of this organelle's structure as they are constantly being bound and released from the membrane.

The functions of the rough endoplasmic reticulum can be summarized:

1- The synthesis and export of proteins and membrane lipids.
2- Manufacture of lysosomal enzymes with a mannose-6-phosphate marker added in the cis-Golgi network.
3- Integral membrane proteins that stay embedded in the cell membrane.

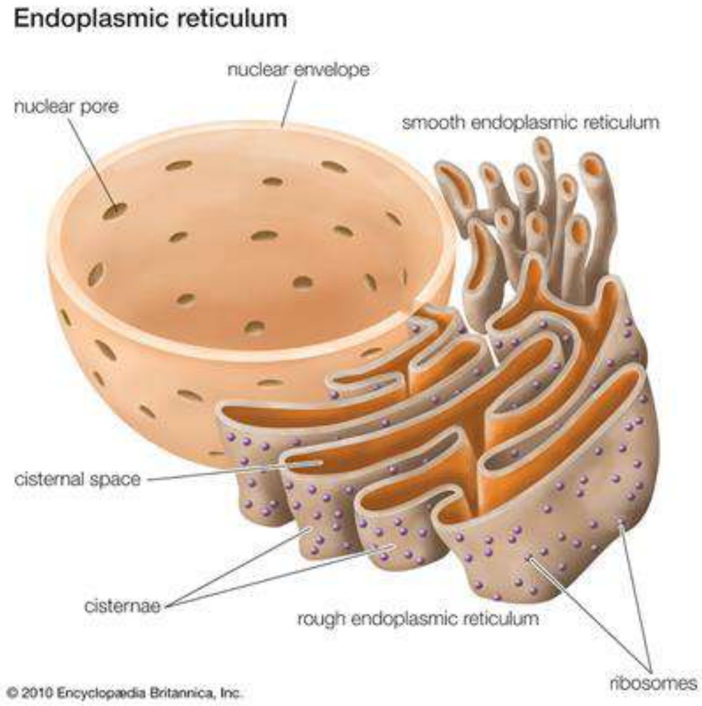
4- Have enzymes that can added carbohydrate chains to protein forming glycoprotein.

II. Smooth endoplasmic reticulum

Smooth endoplasmic reticulum (SER) is an irregular network of folded membranes that are devoid of ribosomes.

The functions of the smooth endoplasmic reticulum can be summarized:

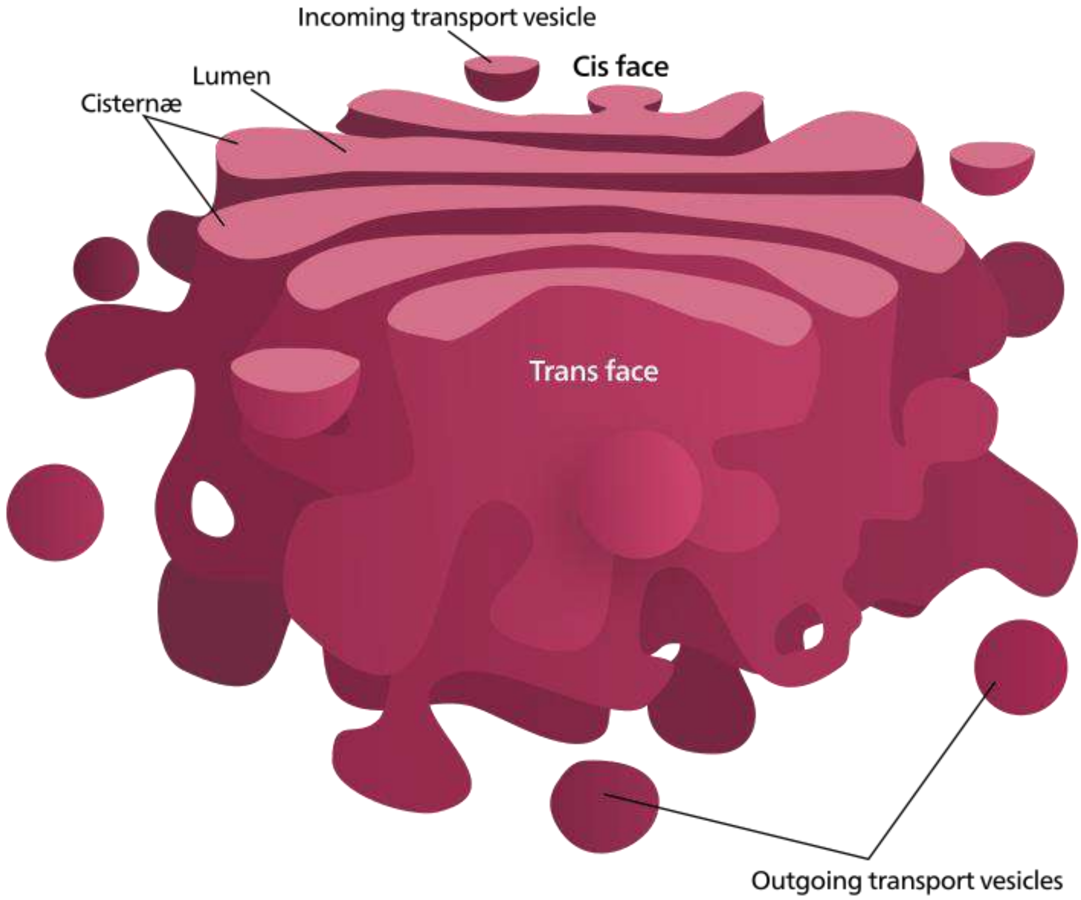
1- The smooth ER is important in the synthesis of lipids, such as cholesterol and phospholipids, which form all the membranes of the cell.
2- In addition, it is important for the synthesis and secretion of steroid hormones from cholesterol and other lipid precursors.
3- In addition, it is involved in carbohydrate metabolism. For instance, the final reaction of gluconeogenesis occurs in the lumen of the smooth ER since it contains the enzyme glucose-6-phosphatase.
4- They are also abundant in liver cells and help in detoxification of drugs.



Golgi apparatus

The Golgi apparatus, also known as the Golgi complex, Golgi body, or simply the Golgi, is an organelle found in most eukaryotic cells. Part of the endomembrane system in the cytoplasm, the Golgi apparatus packages proteins into membrane-bound vesicles inside the cell before the vesicles are sent to their destination.

Proteins synthesized in the ER are packaged into vesicles, which then fuse with the Golgi apparatus. These cargo proteins are modified and destined for secretion via exocytosis or for use in the cell. The Golgi body can be thought of as similar to a post office: it packages and labels items which it then sends to different parts of the cell or to the extracellular space.



3-Cytoskeleton

Cytoskeleton, a system of filaments or fibres that is present in the cytoplasm of eukaryotic cells. The cytoskeleton organizes other constituent of the cell, maintains the cell's shape, and is responsible for the locomotion of the cell itself and the movement of the various organelles within it. It is a complex, dynamic network of interlinking protein filaments that extends from the cell nucleus to the cell membrane. The cytoskeletal matrix is a dynamic structure composed of three main proteins, which are capable of rapid growth or disassembly dependent on the cell's requirements.

The three main structural components of the cytoskeleton are **microtubules** (formed by tubulins), **microfilaments** (formed by actins) and **intermediate filaments**. All three components interact with each other non-covalently

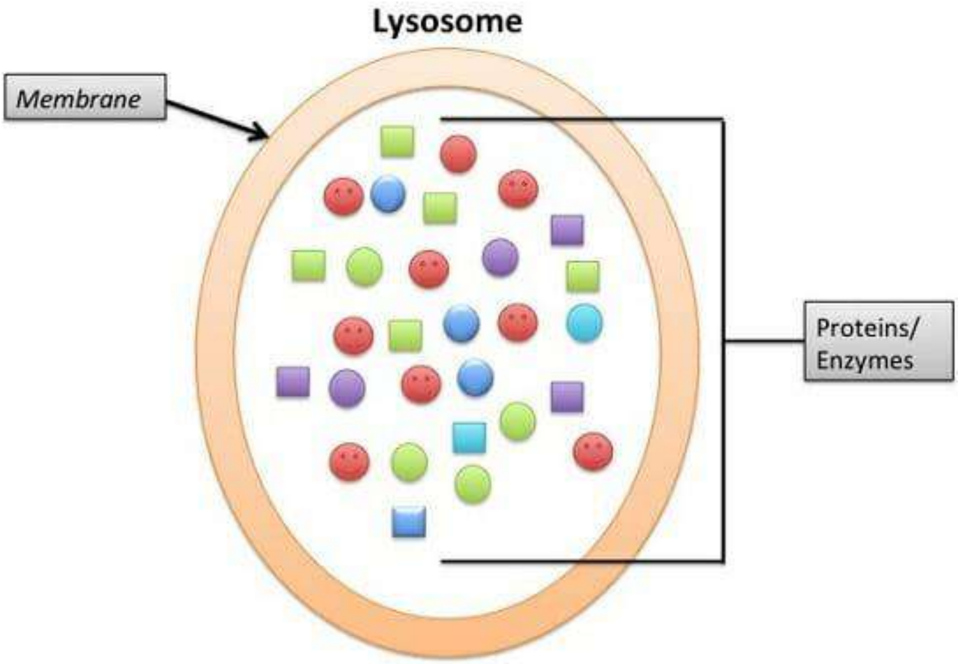
Functions:

Microtubules help in maintenance of cell shape, intracellular transport and formation of mitotic spindles during mitosis.

5. Lysosomes

Lysosomes act as the waste disposal system of the cell by digesting obsolete or un-used materials in the cytoplasm, from both inside and outside the cell. Material (complex molecules such as carbohydrates, lipids, proteins, and nucleic acids) from outside the cell is taken-up through endocytosis, while material from the inside of the cell is digested through autophagy. Lysosomes are known to contain more than 60 different enzymes, and have more than 50 membrane proteins. Enzymes of the lysosomes are synthesised in the rough endoplasmic reticulum.

Synthesis of lysosomal enzymes is controlled by nuclear genes. Mutations in the genes for these enzymes are responsible for more than 30 different human genetic disorders, which are collectively known as lysosomal storage diseases. These diseases result from an accumulation of specific substrates, due to the inability to break them down. These genetic defects are related to several neurodegenerative disorders, cancers, cardiovascular diseases, and aging-related diseases.

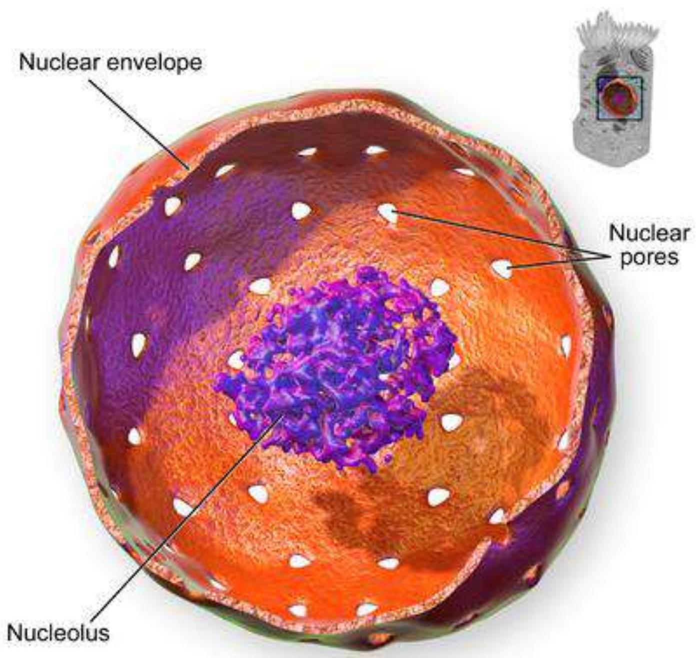


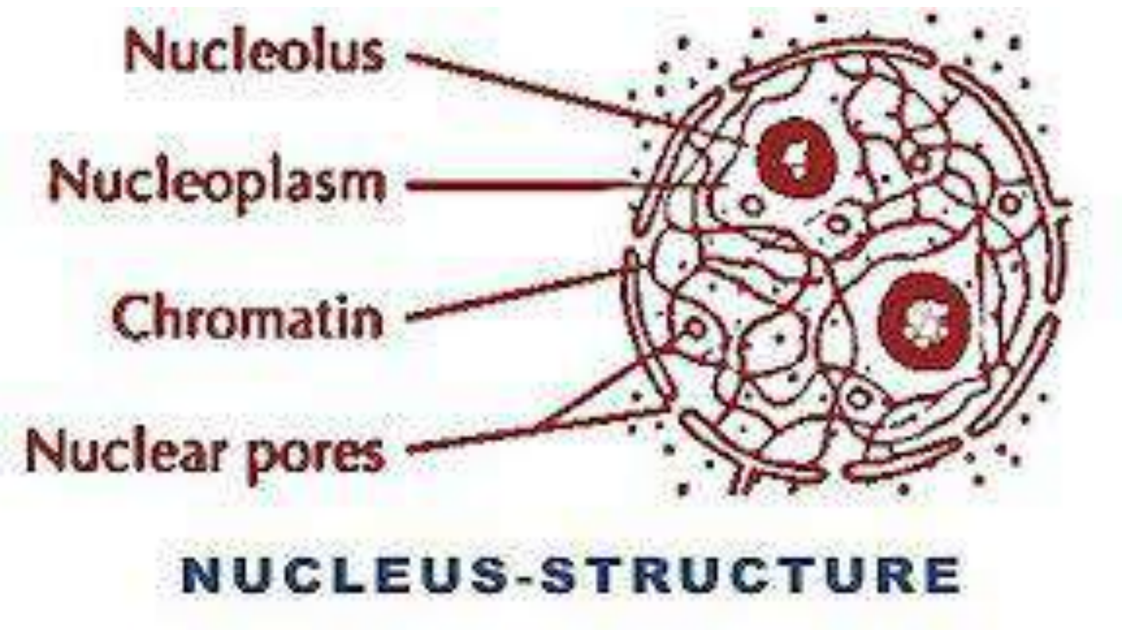
6. Nucleus

The nucleus is a membrane-bound organelle that contains genetic material (DNA) of eukaryotic organisms. As such, it serves to maintain the integrity of the cell by facilitating transcription and replication processes. It's the largest organelle inside the cell taking up about a tenth of the entire cell volume. This makes it one of the easiest organelles to identify under the microscope. Some eukaryotic cells lack a nucleus and are referred to as enucleate cells (e.g. erythrocytes) while others may have more than one nucleus (e.g. slime moulds).

Function

The nucleus provides a site for genetic transcription that is segregated from the location of translation in the cytoplasm, allowing levels of gene regulation that are not available to prokaryotes. The main function of the cell nucleus is to control gene expression and mediate the replication of DNA during the cell cycle.



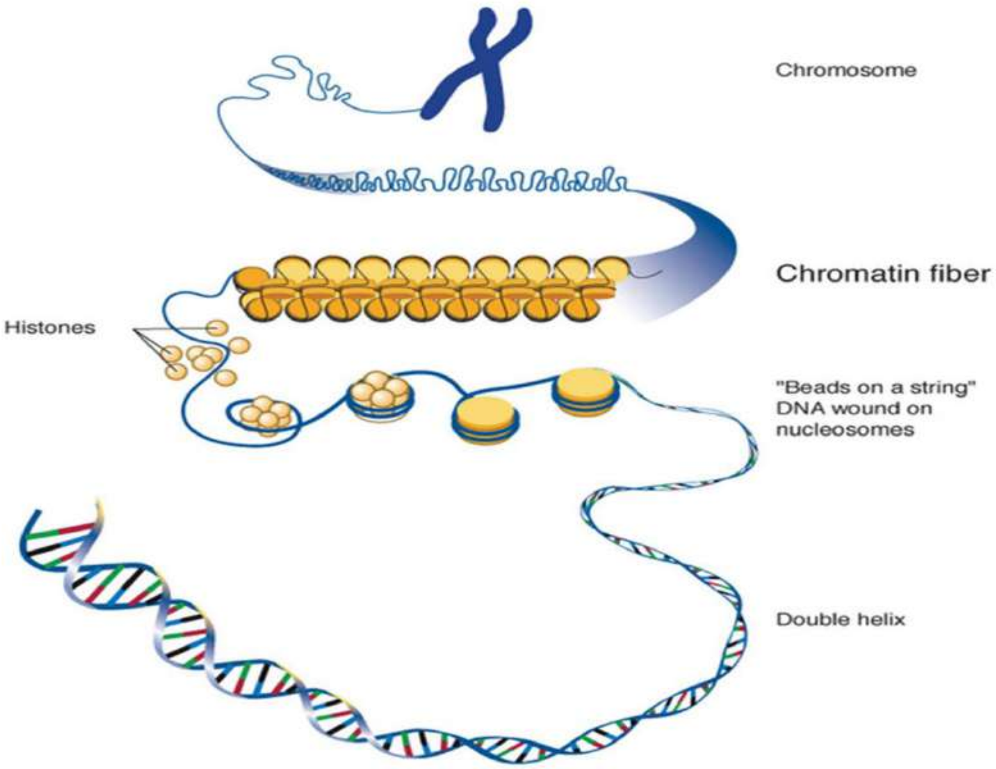


Chromatin

Chromatin is a complex of macromolecules found in cells, consisting of DNA, protein, and RNA. The primary functions of chromatin are (1) to package DNA into a more compact, denser shape, (2) to reinforce the DNA macromolecule to allow mitosis. (3) to prevent DNA damage, and (4) to control gene expression and DNA replication.

Chromosomes

● A chromosome consists of a highly folded and condensed single DNA molecule. The associated proteins help in organization of the DNA.
● Chromosomes are best seen during cell division when they reach maximum condensation.
● Each chromosome consists of a short arm (p) and a long arm (q); they are connected to each other by a constricted region known as centromere.
● After DNA replication, chromosomes consist of a pair of identical chromatids joined by a centromere.



Nucleus chemical composition:

- 9-12 percent DNA
- 15 percent histone
- 65 percent enzymes, neutral proteins and acid proteins
- 5 percent RNA
- 3 percent lipids

Some of the main functions of the nucleus include:

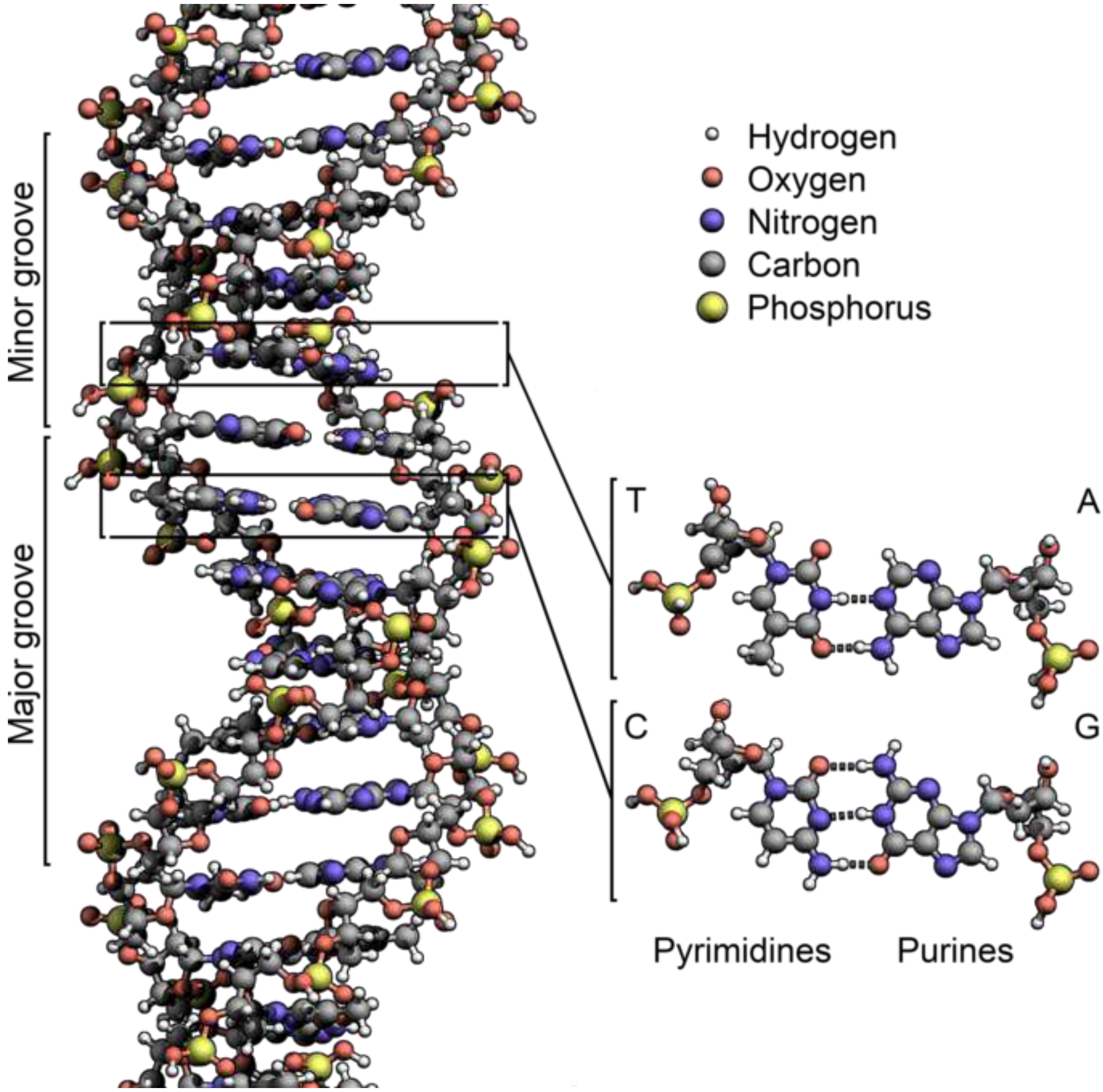
- Protein synthesis, cell division, and differentiation
- Control the synthesis of enzymes involved in cellular metabolism
- Controlling hereditary traits of the organism
- Store DNA strands, proteins, and RNA
- Site of RNA transcription - e.g. mRNA required for protein synthesis

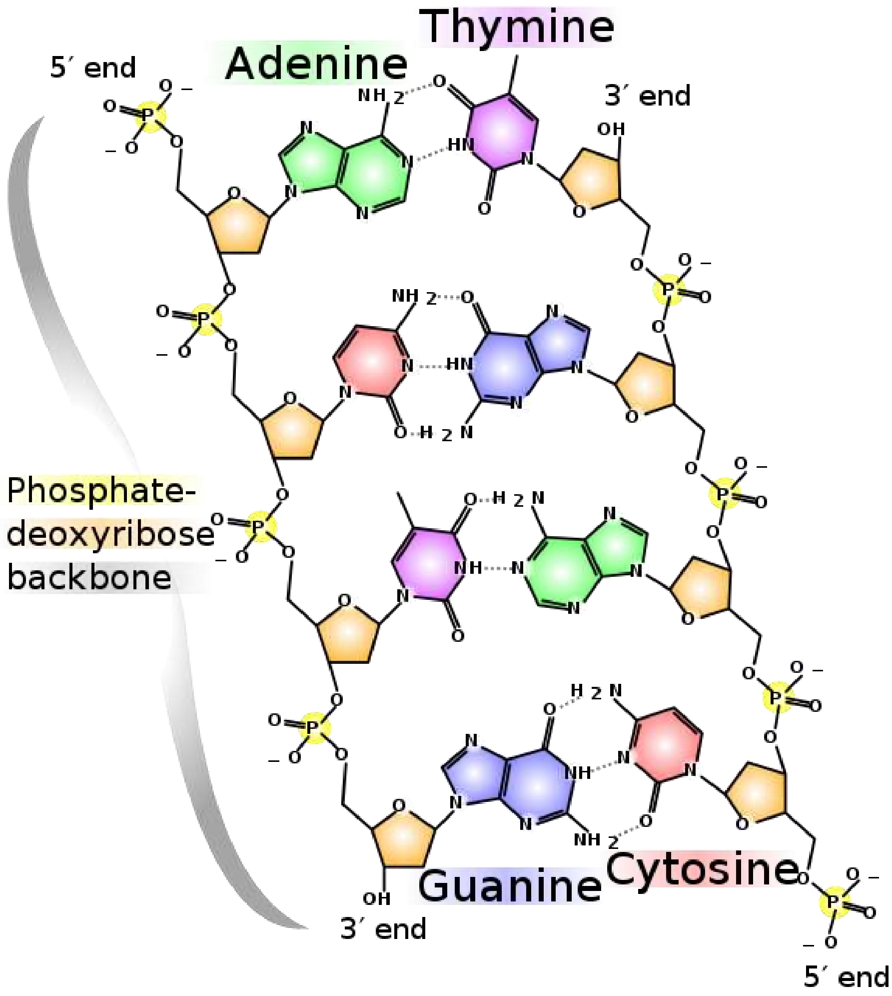
Deoxyribonucleic acid (DNA)

Deoxyribonucleic acid (DNA) is a molecule composed of two chains that coil around each other to form a double helix carrying genetic instructions for the development, functioning, growth and reproduction of all know organisms and many viruses. DNA and ribonucleic acid (RNA) are nucleic acids; alongside proteins, lipids and complex carbohydrates (polysaccharides), nucleic acids are one of the four major types of macromolecules that are essential for all known forms of life.

The two DNA strands are also known as polynucleotides as they are composed of simpler monomeric units called nucleotides. Each nucleotide is composed of one of four nitrogen- containing nucleobases (cytosine [C], guanine [G], adenine [A] or thymine [T]), a sugar called deoxyribose, and a phosphate group. The nucleotides are joined to one another in a chain by covalent bonds between the sugar of one nucleotide and the phosphate of the next, resulting in an alternating sugar-phosphate backbone.

The nitrogenous bases of the two separate polynucleotide strands are bound together, according to base pairing rules (A with T and C with G), with hydrogen bonds to make double-stranded DNA. The complementary nitrogenous bases are divided into two groups, pyrimidines and purines. In DNA, the pyrimidines are thymine and cytosine; the purines are adenine and guanine.

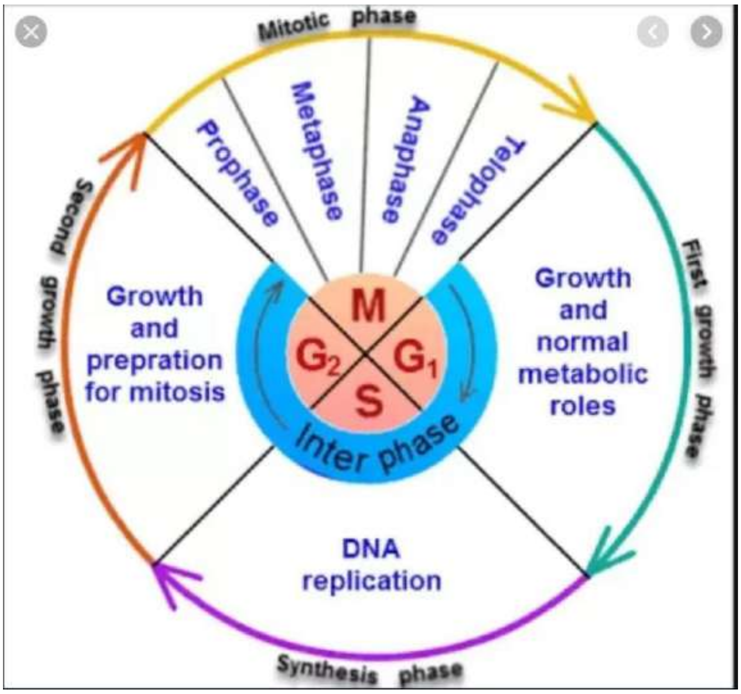




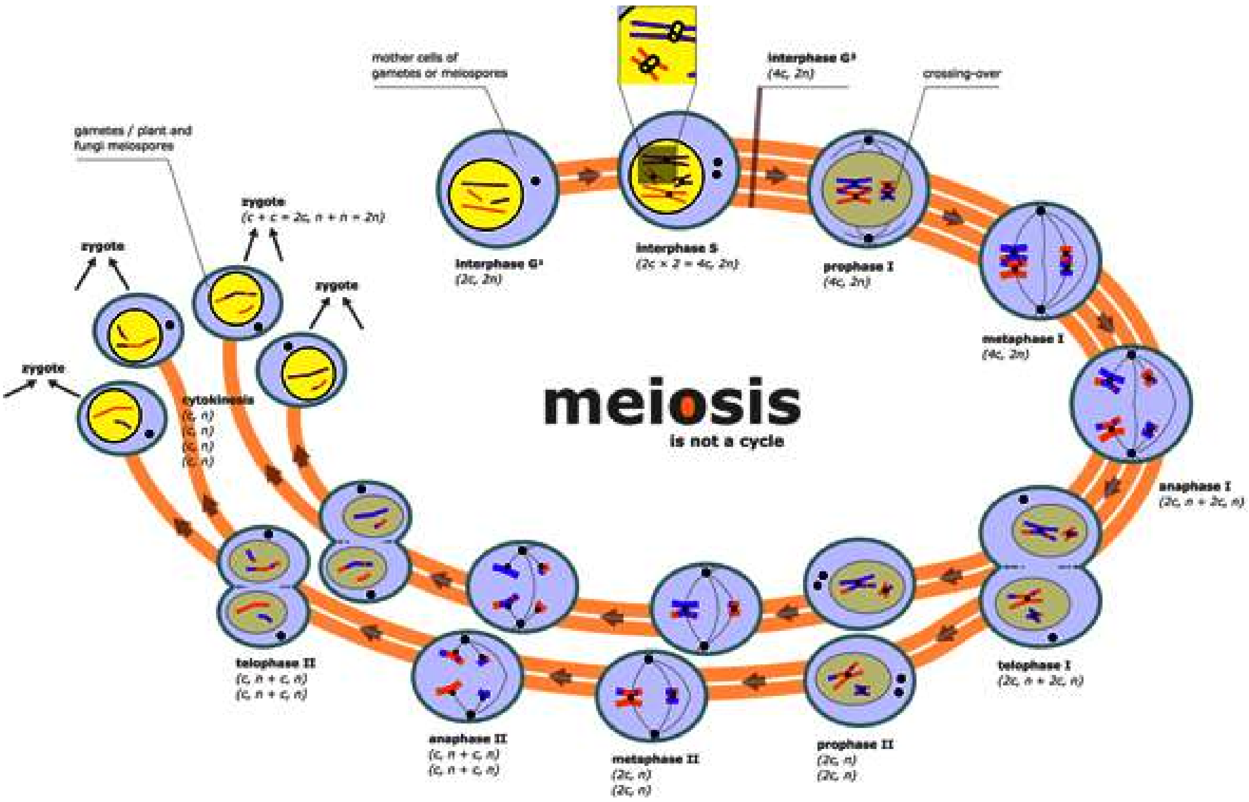
How do cells divide?

There are two types of cell division: mitosis and meiosis. Most of the time when people refer to “cell division,” they mean mitosis, the process of making new body cells. Meiosis is the type of cell division that creates egg and sperm cells.

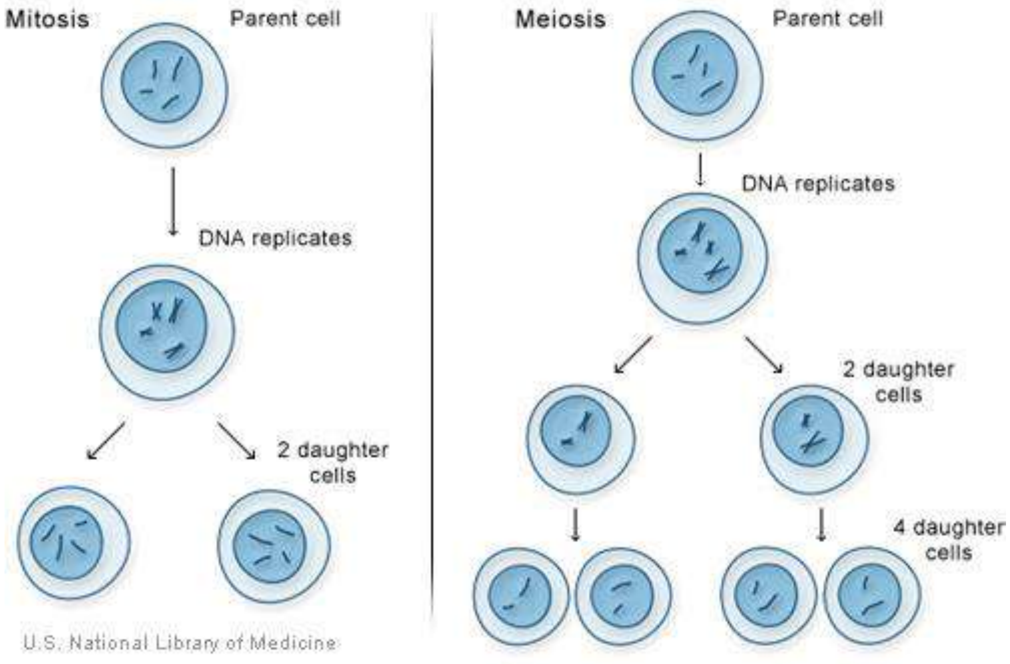
Mitosis is a fundamental process for life. During mitosis, a cell duplicates all of its contents, including its chromosomes, and splits to form two identical daughter cells. Because this process is so critical, the steps of mitosis are carefully controlled by a number of genes. When mitosis is not regulated correctly, health problems such as cancer can result.



The other type of cell division, meiosis, ensures that humans have the same number of chromosomes in each generation. It is a two-step process that reduces the chromosome number by half—from 46 to 23—to form sperm and egg cells. When the sperm and egg cells unite at conception, each contributes 23 chromosomes so the resulting embryo will have the usual 46. Meiosis also allows genetic variation through a process of DNA shuffling while the cells are dividing.



Mitosis and meiosis, the two types of cell division.



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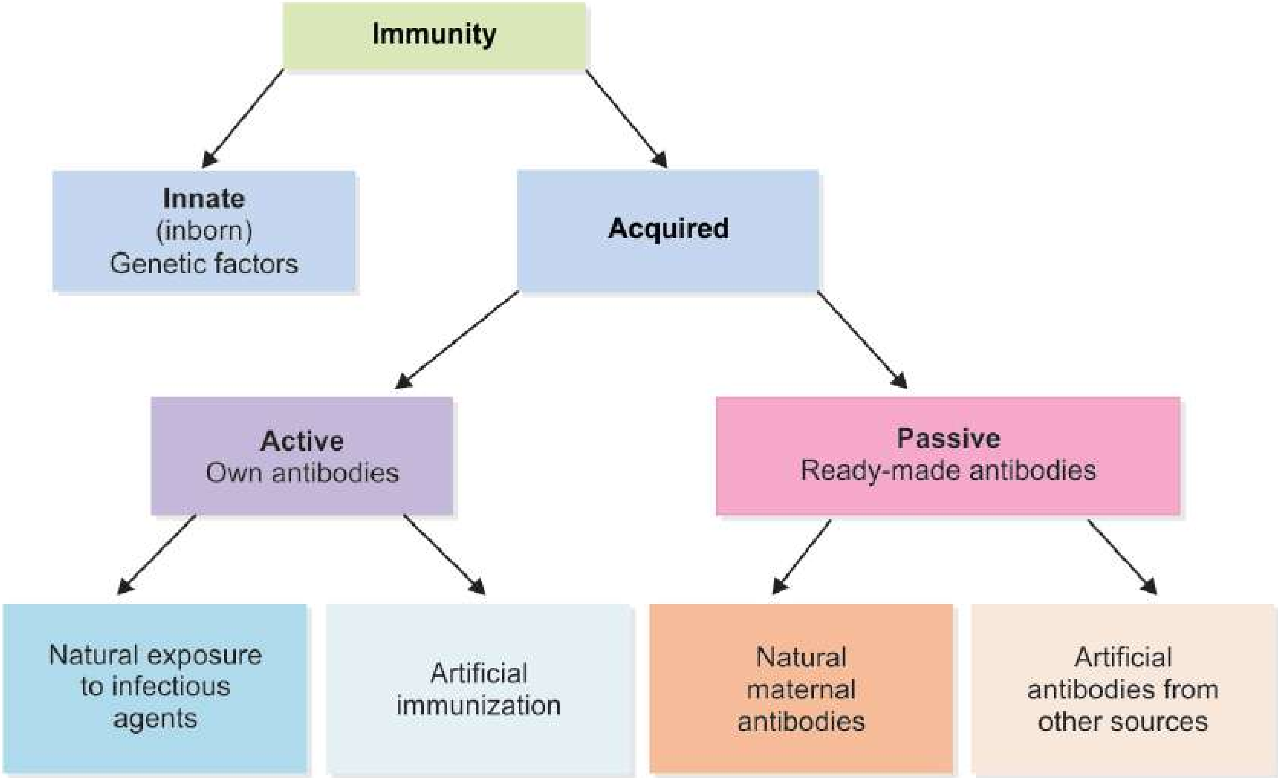
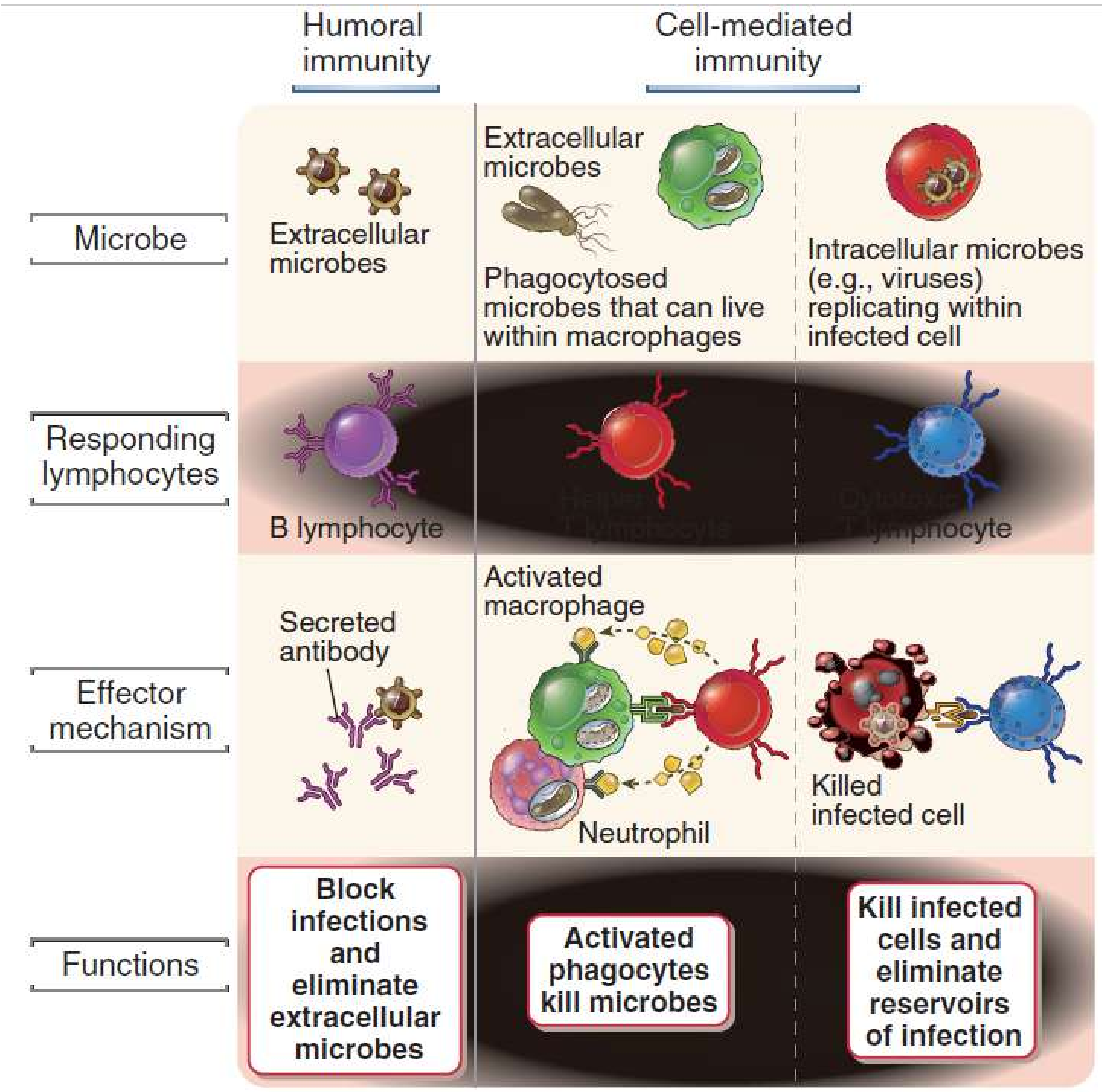
Immunity



Adaptive immunity

The adaptive immune response is mediated by cells called lymphocytes and their products. Lymphocytes express highly diverse receptors that can recognize a vast number of antigens. There are two major populations of lymphocytes, called **B lymphocytes** and **T lymphocytes**, which mediate different types of adaptive immune responses.

The adaptive immune responses take some days and weeks to be finished. However, they are more effective in eliminating invading pathogens than the innate immunity. Furthermore, they develop the immune memory to the invading pathogens. There are two types of adaptive immunity, called humoral immunity and cell-mediated immunity, which are induced by different types of lymphocytes and function to eliminate different types of microbes (Figs. below).



B-Cell-Mediated (Humoral) Responses

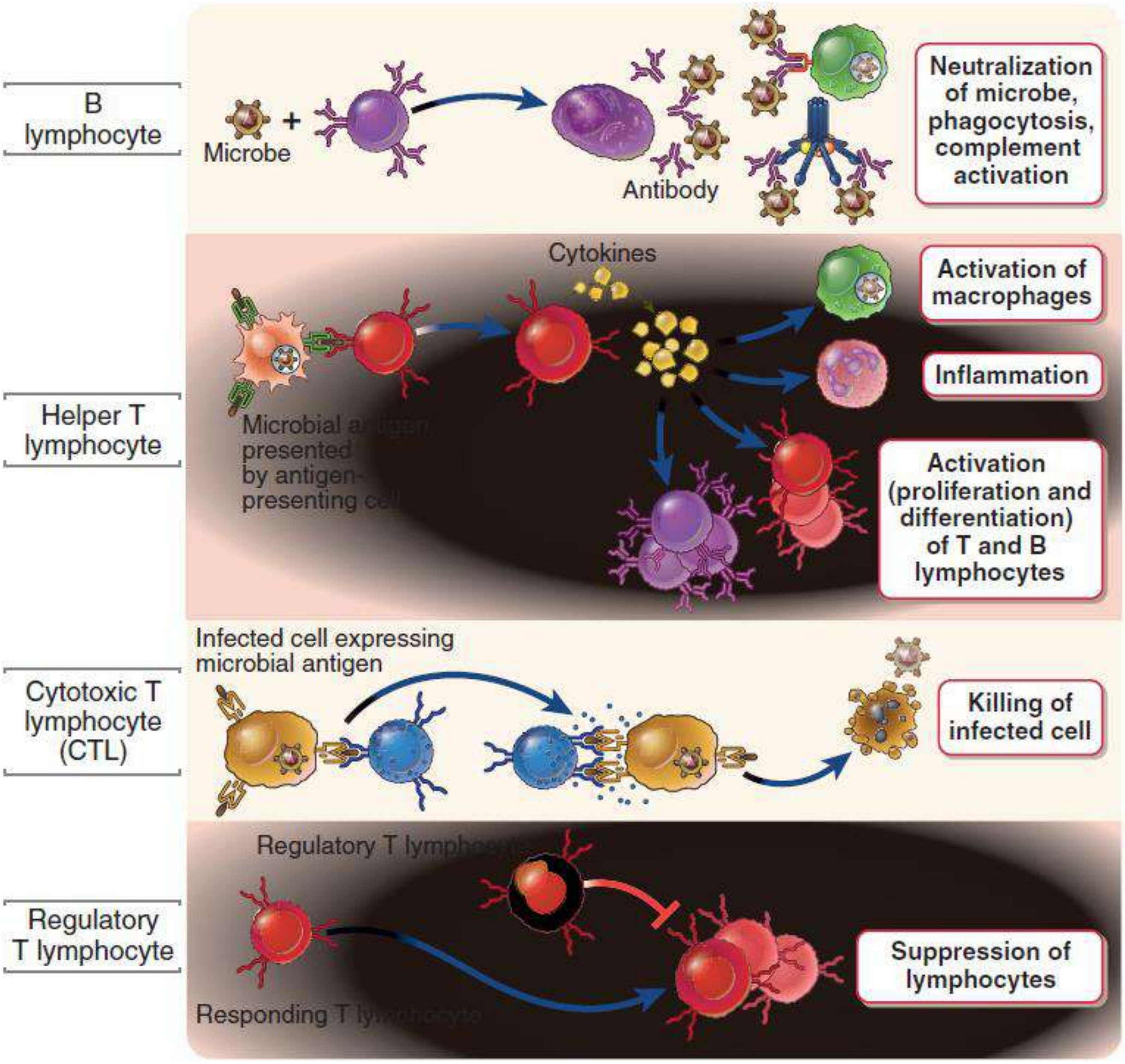
1. Simple B-cell response formation of only one class of immunoglobulins, IgM, but no long-term memory. This type of response may be triggered by “patterns” too.

2. Advanced B-cell response – switching antibodies after each other: IgM, IgG, IgA, and even IgE, and inducing the formation of long-lived memory plasma cells and lifelong memory B cells.

- **T-Cell-Mediated Responses**

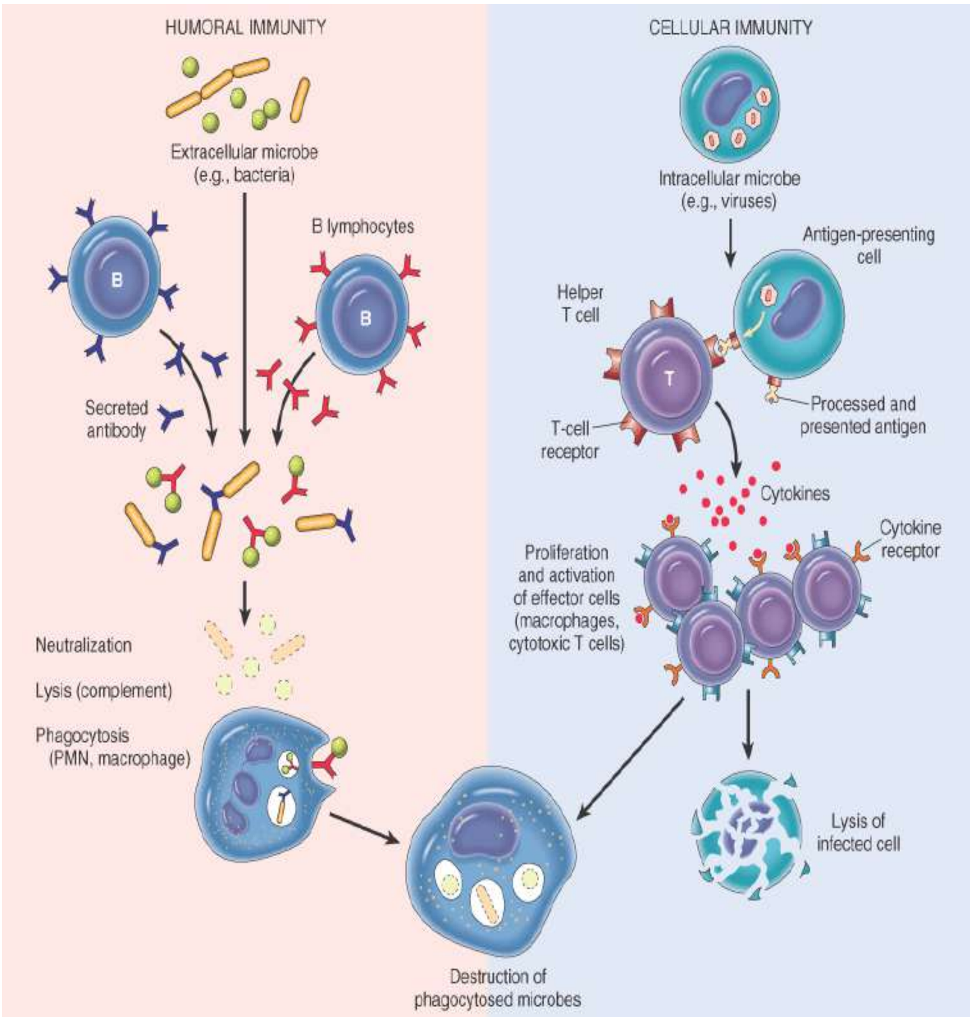
3. Inflammatory CD4+T-cell response that leads to the production of effector CD4+T cells and the lifelong memory CD4+T cells.

4. Cytotoxic CD8+T-cell response, which results in the formation of cytotoxic CD8+T cells capable of apoptosis in target cells and lifelong memory CD8+T cells.



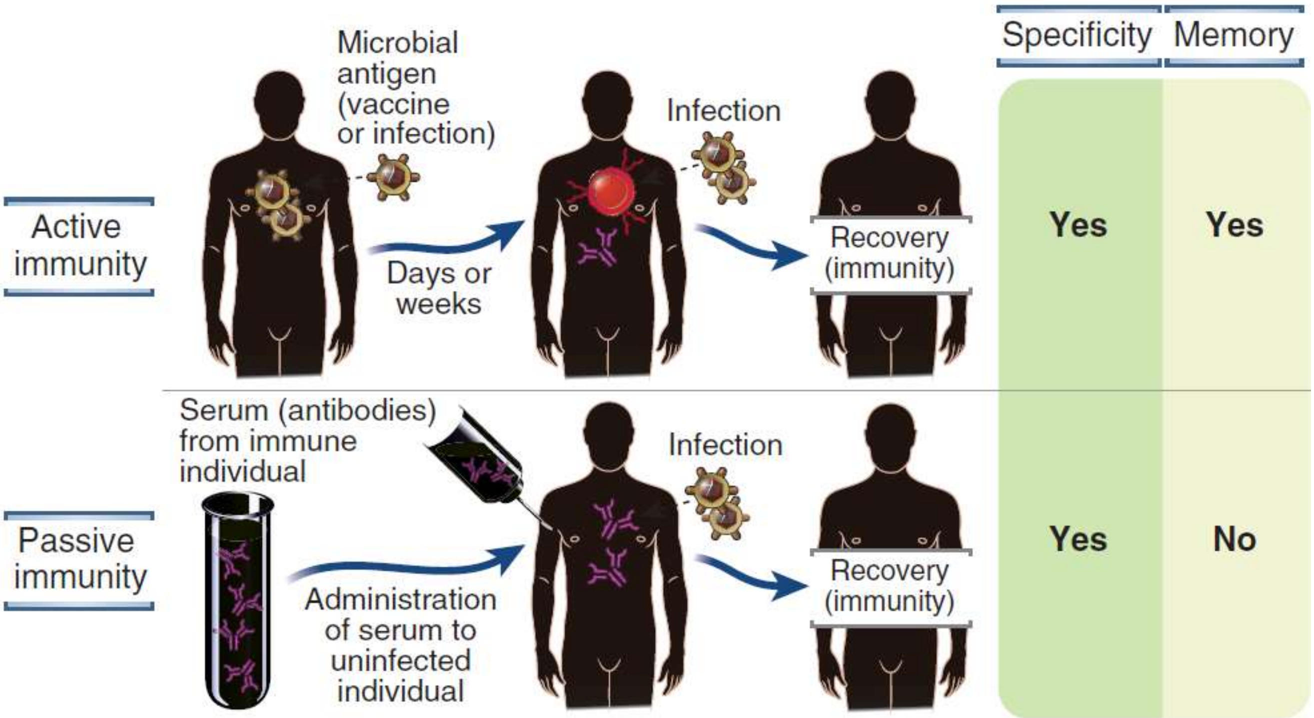
Humoral immunity is mediated by molecules in the blood and mucosal secretions, called antibodies, which are produced by B lymphocytes. Antibodies recognize microbial antigens, neutralize the infectivity of the microbes, and target microbes for elimination by phagocytes and the complement system. Humoral immunity is the principal defense mechanism against microbes and their toxins located outside cells (e.g. in the lumens of the gastrointestinal and respiratory tracts and in the blood) because secreted antibodies can bind to these microbes and toxins, neutralize them, and assist in their elimination.

Cell-mediated immunity, also called cellular immunity, is mediated by T lymphocytes. Many microbes are ingested by but survive within phagocytes, and some microbes, notably viruses, infect and replicate in various host cells. In these locations the microbes are inaccessible to circulating antibodies. Defense against such infections is a function of cell-mediated immunity, which promotes the destruction of microbes inside phagocytes and the killing of infected cells to eliminate reservoirs of infection.



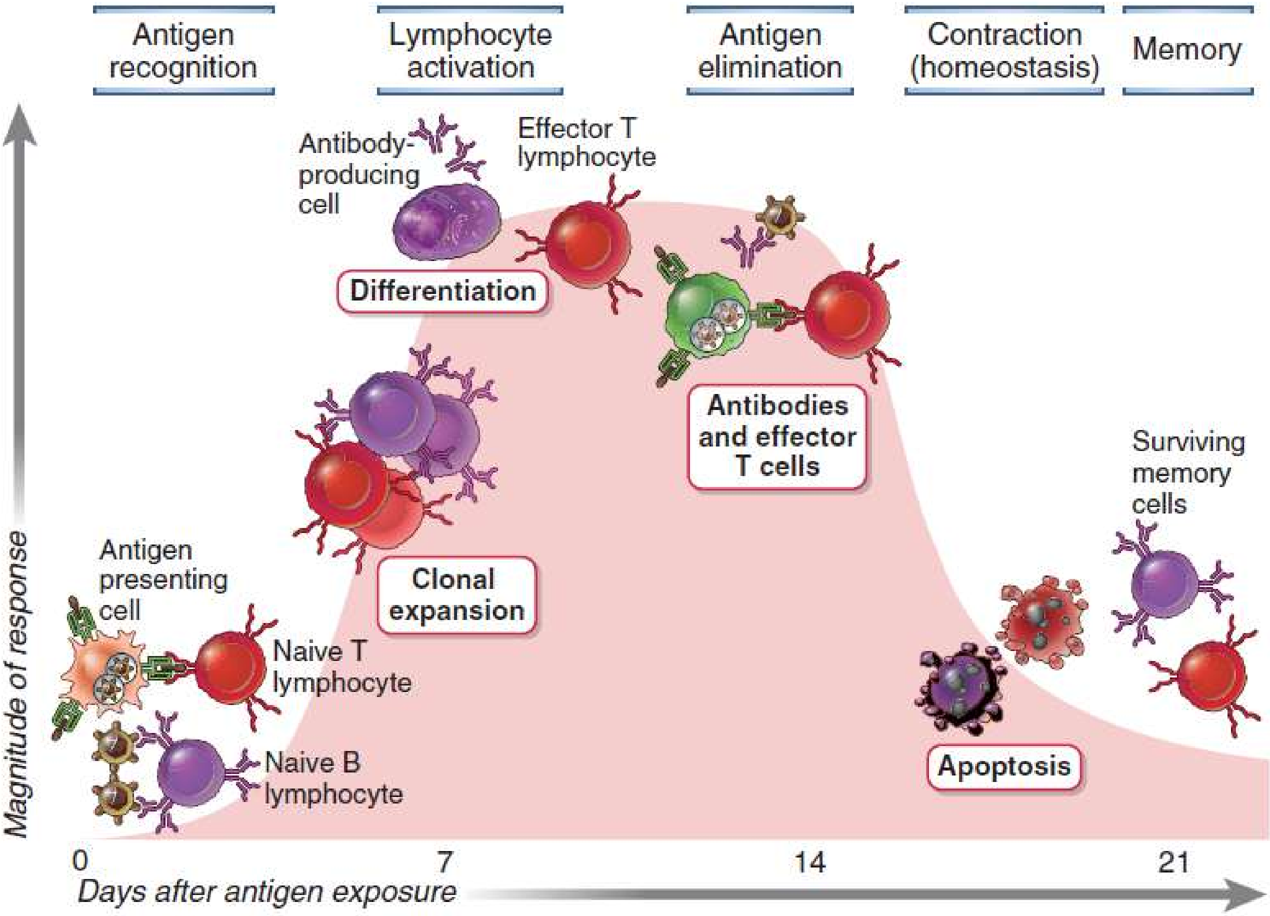
Protective immunity against a microbe may be provided either by the host's response to the microbe or by the transfer of antibodies that defend against the microbe. The form of immunity that is induced by exposure to a foreign antigen is called **Active immunity** because the immunized individual plays an active role in responding to the antigen. Individuals and lymphocytes that have not encountered a particular antigen are said to be naive, implying that they are immunologically inexperienced. Individuals who have responded to a microbial antigen and are protected from subsequent exposures to that microbe are said to be immune.

Immunity can also be conferred on an individual by transferring antibodies from an immunized individual into an individual who has not encountered the antigen (see Fig. below). The recipient of such a transfer becomes immune to the particular antigen without ever having been exposed to or having responded to that antigen. Therefore, this form of immunity is called **Passive immunity**. A physiologically important example of passive immunity is the transfer of maternal antibodies through the placenta to the fetus, which enables newborns to combat infections for several months before they develop the ability to produce antibodies themselves. Passive immunization is also a medically useful method for conferring resistance rapidly, without having to wait for an active immune response to develop. Passive immunization against potentially lethal toxins by the administration of antibodies from immunized animals or people is a lifesaving treatment for rabies infection and snake bites. Patients with some genetic immunodeficiency diseases are passively immunized by transfer of pooled antibodies from healthy donors.



Initiation and Development of Adaptive Immune Responses

Adaptive immune responses develop in several steps, starting with the capture of antigen, followed by the activation of specific lymphocytes (Fig. below). Most microbes and other antigens enter through epithelial barriers and adaptive immune responses to these antigens develop in peripheral (secondary) lymphoid organs. The initiation of adaptive immune responses requires that antigens be captured and displayed to specific lymphocytes. The cells that serve this role are called **antigen-presenting cells (APCs)**. The most specialized APCs are **dendritic cells**, which capture microbial antigens that enter from the external environment, transport these antigens to lymphoid organs, and present the antigens to naive T lymphocytes to initiate immune responses. Other cell types function as APCs at different stages of cell-mediated and humoral immune responses.



The activation of these lymphocytes by antigen leads to the proliferation of these cells, resulting in an increase in the size of the antigen-specific clones, called clonal expansion. This is followed by differentiation of the activated lymphocytes into cells capable of eliminating the antigen, called effector cells because they mediate the ultimate effect of the immune response, and memory cells that survive for long periods and mount strong responses to repeat antigen encounter. Antigen elimination often requires the participation of other, nonlymphoid cells, such as macrophages and neutrophils, which are also sometimes called effector cells. These steps in lymphocyte activation typically take a few days, which explains why the adaptive response is slow to develop and innate immunity has to provide protection initially.

After the adaptive immune response has eradicated the infection, the stimuli for lymphocyte activation dissipate and most of the effector cells die, resulting in the decline of the response. Memory cells remain, ready to respond vigorously if the same infection recurs. The cells of the immune system interact with one another and with other host cells during the initiation and effector stages of innate and adaptive immune responses. Many of these interactions are mediated by cytokines. Cytokines are a large group of secreted proteins with diverse structures and functions, which regulate and coordinate many activities of the cells of innate and adaptive immunity. All cells of the immune system secrete at least some cytokines and express specific signaling receptors for several cytokines.

Humoral Immunity (Whole Story)

B lymphocytes that recognize antigens proliferate and differentiate into plasma cells that secrete different classes of antibodies with distinct functions. Each clone of B cells expresses a cell surface antigen receptor, which is a membrane-bound form of antibody, with a unique antigen specificity. Many different types of antigens, including proteins, polysaccharides, lipids, and small molecules, are capable of eliciting antibody responses.

The response of B cells to protein antigens requires activating signals (help) from CD4+ T cells (which is the historical reason for calling these T cells helper cells). B cells can respond to many nonprotein antigens without the participation of helper T cells. Each plasma cell secretes antibodies that have the same antigen-binding site as the cell surface antigen receptor that first recognized the antigen. Polysaccharides and lipids stimulate secretion mainly of the antibody class called immunoglobulin M (IgM). Protein antigens induce the production of antibodies of different classes (IgG, IgA, IgE) from a single clone of B cells. These different antibody classes serve distinct functions, mentioned later. Helper T cells also stimulate the production of antibodies with increased affinity for the antigen. This process, called affinity maturation, improves the quality of the humoral immune response. The humoral immune response combats microbes in many ways. Antibodies bind to microbes and prevent them from infecting cells, thus neutralizing the microbes. In fact, antibody-mediated neutralization is the only mechanism of adaptive immunity that stops an infection before it is established; this is why eliciting the production of potent antibodies is a key goal of vaccination. IgG antibodies coat microbes and target them for phagocytosis because phagocytes (neutrophils and macrophages) express receptors for parts of IgG molecules. IgG and IgM activate the complement system, and complement products promote phagocytosis and destruction of microbes. IgA is secreted from mucosal epithelia and neutralizes microbes in the lumens of mucosal tissues, such as the respiratory and gastrointestinal tracts, thus preventing inhaled and ingested microbes from infecting the host. Maternal IgG is actively transported across the placenta and protects the newborn until the baby's immune system becomes mature. Most IgG antibodies have half-lives in the circulation of approximately 3 weeks, whereas other classes of antibodies have half-lives of just a few days. Some antibody-secreting plasma cells migrate to the bone marrow or mucosal tissues and live for years, continuing to produce low levels of antibodies. The antibodies that are secreted by these long-lived plasma cells provide immediate protection if the microbe return to infect the individual. More effective protection is provided by memory cells that are activated by the microbe and rapidly differentiate to generate large numbers of plasma cells.

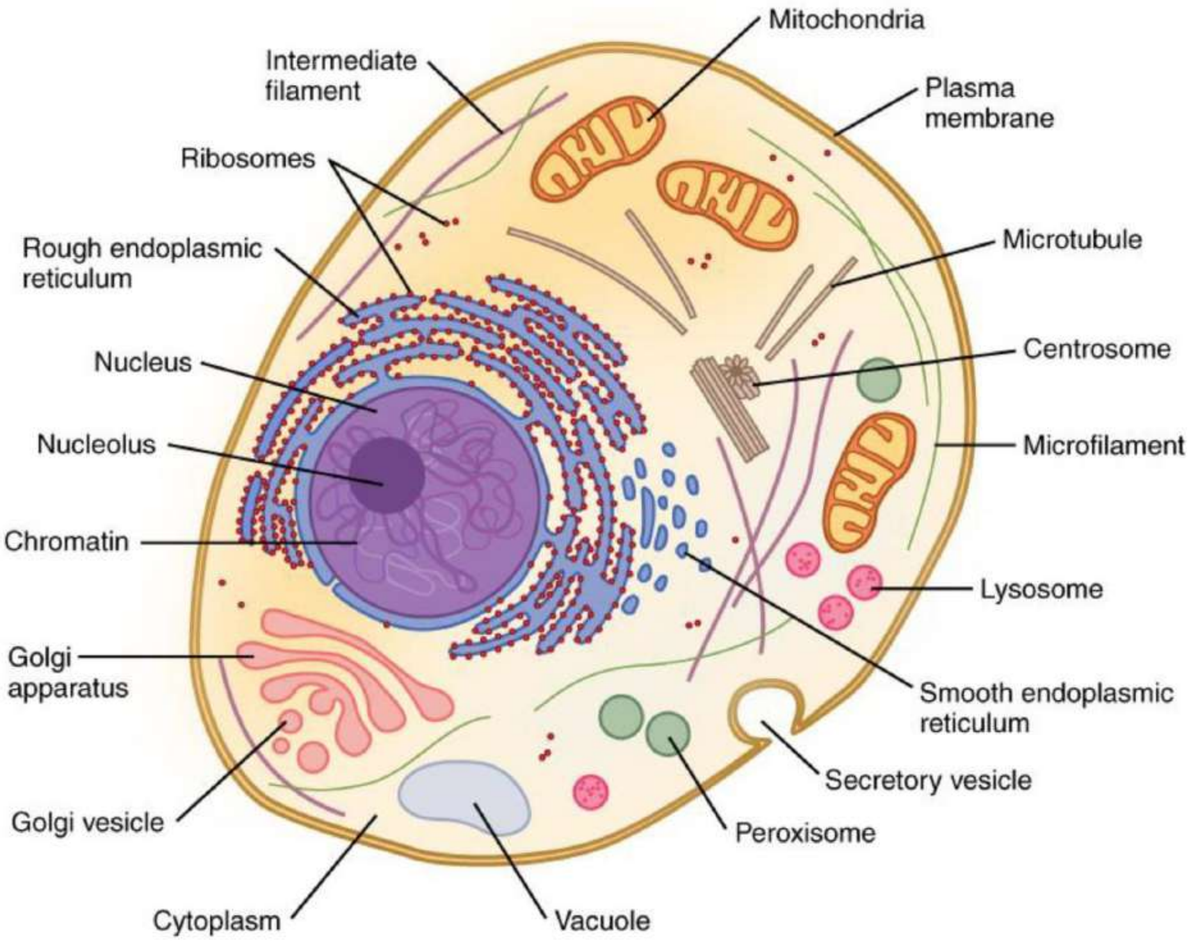
Cell-Mediated Immunity (Whole Story)

T lymphocytes, the cells of cell-mediated immunity, recognize the antigens of cell-associated microbes, and different types of T cells help phagocytes to destroy these microbes or kill the infected cells. T cells do not produce antibody molecules. Their antigen receptors are membrane molecules distinct from but structurally related to antibodies (**see Lec8**). T lymphocytes have a restricted specificity for antigens; they recognize peptides derived from foreign proteins that are bound to host proteins called major histocompatibility complex (MHC) molecules, which are expressed on the surfaces of other cells. As a result, these T cells recognize and respond to cell surface associated but not soluble antigens. T lymphocytes consist of functionally distinct populations, the best defined of which are helper T cells and cytotoxic (or cytolytic) T lymphocytes (CTLs). The functions of helper T cells are mediated mainly by secreted cytokines, whereas CTLs produce molecules that kill other cells. Some T lymphocytes, which are called regulatory T cells, function mainly to inhibit immune responses. Different classes of lymphocytes can be distinguished by the expression of cell surface proteins, many of which are designated by a unique "CD" number, such as CD4 or CD8. Upon activation in secondary lymphoid organs, naïve T lymphocytes differentiate into effector cells, and many of them leave and migrate to sites of infection. When these effector T cells again encounter cell-associated microbes, they are activated to perform the functions that are responsible for elimination of the microbes. Some CD4+ helper T cells secrete cytokines that recruit leukocytes and stimulate production of microbicidal substances in phagocytes. Thus, these T cells help phagocytes to kill the infectious pathogens. Other CD4+ helper T cells secrete cytokines that help B cells to produce a type of antibody called IgE and activate leukocytes called eosinophils, which are able to kill parasites that may be too large to be phagocytosed. Some CD4+ helper T cells stay in the lymphoid organs and stimulate B cell responses. CD8+ CTLs kill cells harboring microbes in the cytoplasm. These microbes may be viruses that infect many cell types or bacteria that are ingested by macrophages but escape from phagocytic vesicles into the cytoplasm (where they are inaccessible to the killing machinery of phagocytes, which is largely confined to vesicles). By destroying the infected cells, CTLs eliminate the reservoirs of infection. CTLs also kill tumor cells that express antigens that are recognized as foreign.

Cell structure and function

A **cell** is the smallest living thing in the human organism, and all living structures in the human body are made of cells. There are hundreds of different types of cells in the human body, which vary in ① **shape** (e.g. round, flat, long and thin, short and thick) and ② size (e.g. small granule cells of the cerebellum in the brain (4 micrometers), up to the huge oocytes (eggs) produced in the female reproductive organs (100 micrometers) and ③ function.

However, all cells have three main parts, the **plasma membrane**, the **cytoplasm** and the nucleus. The **plasma membrane** (often called the cell membrane) is a thin flexible barrier that separates the inside of the cell from the environment outside the cell and regulates what can pass in and out of the cell.



Internally, the cell is divided into the cytoplasm and the nucleus. The **cytoplasm** is where most functions of the cell are carried out. It looks a bit-like mixed fruit jelly, where the watery jelly is called the **cytosol**; and the different fruits in it are called **organelles**. The cytosol also contains many molecules and ions involved in cell functions. Different organelles also perform different cell functions, and many are also separated from the cytosol by membranes. The largest organelle, the **nucleus** is separated from the cytoplasm by a nuclear envelope (membrane). It contains the DNA (genes) that code for proteins necessary for the cell to function.

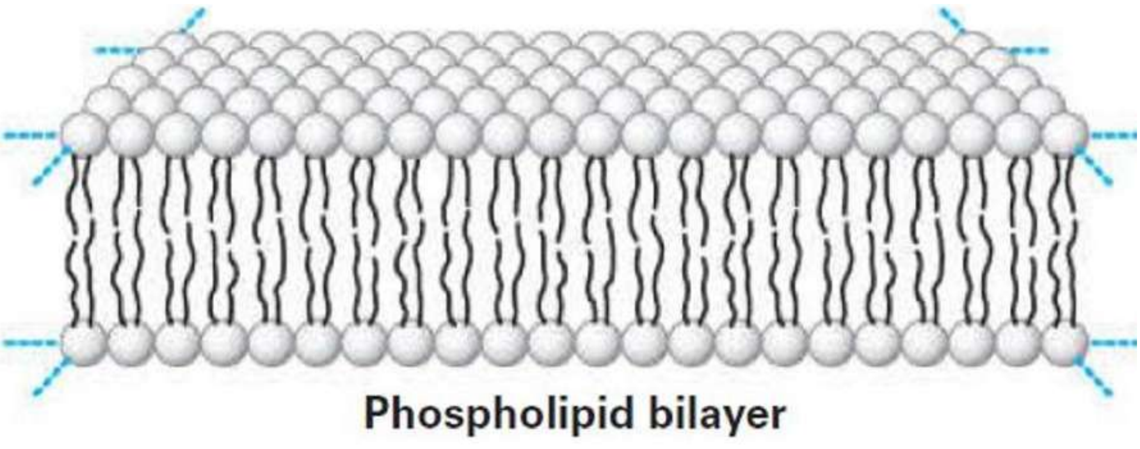
1- The cell membrane, or plasma membrane

The cell membrane, or plasma membrane, is a biological membrane that surrounds the cytoplasm of a cell. In animals, the plasma membrane is the outer boundary of the cell, while in plants and prokaryotes it is usually covered by a cell wall. This membrane serves to separate and protect a cell from its surrounding environment. Membranes have been chemically analyzed and found to be made of proteins and lipids, therefore, the Membrane Structure has 4 components:

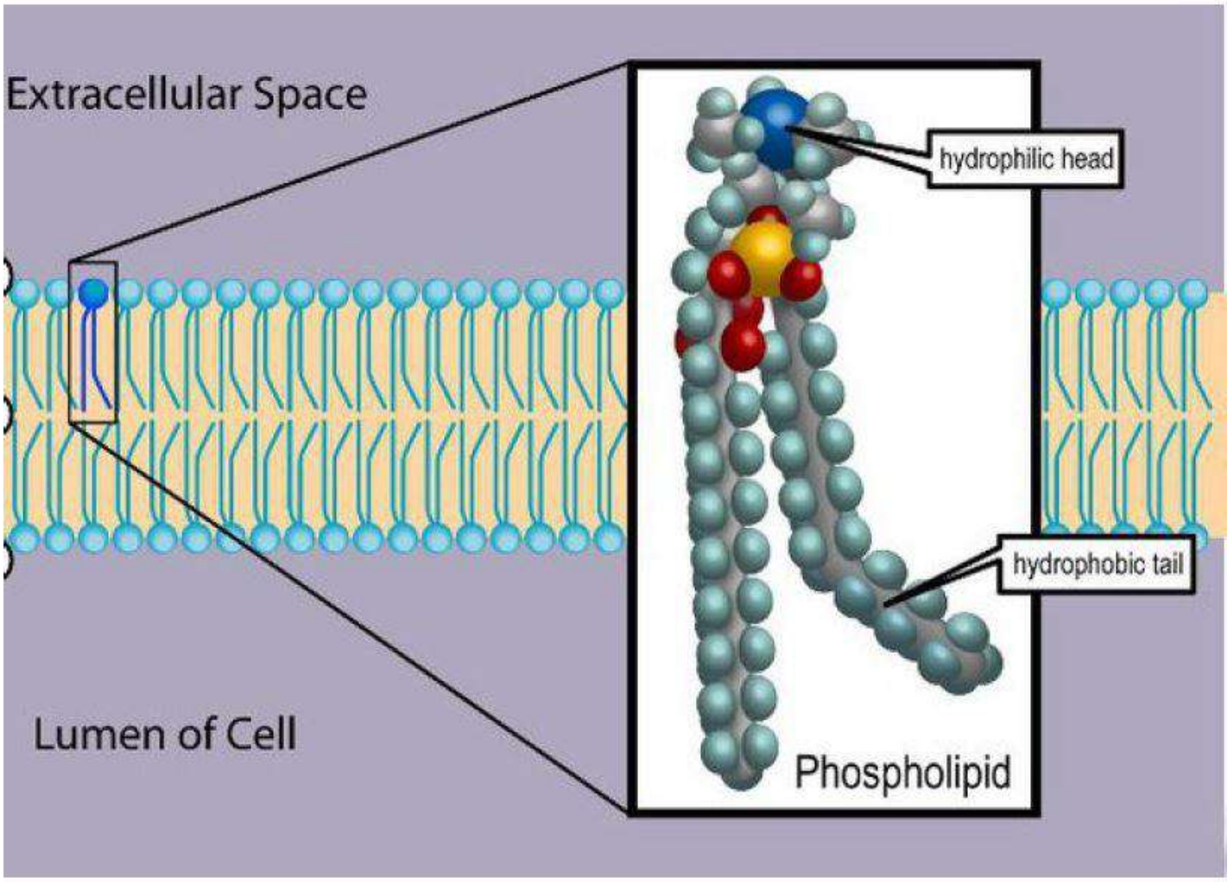
1. Phospholipid bilayer.
2. Transmembrane proteins (Integral membrane protein).
3. Interior protein network (Peripheral membrane proteins).
4. Cell surface markers.

1- Phospholipid bilayer

It is made mostly from a double layer of phospholipids, which are amphiphilic (partly hydrophobic and partly hydrophilic). Hence, the layer is called a phospholipid bilayer. The plasma (cell) membrane separates the inner environment of a cell from the extracellular fluid. It is composed of a fluid **phospholipid bilayer** (two layers of phospholipids) as shown in **figure below (Fig 2)**, and other molecules. Not many substances can cross the phospholipid bilayer, so it serves to separate the inside of the cell from the extracellular fluid.



(Fig 2)



Phospholipid

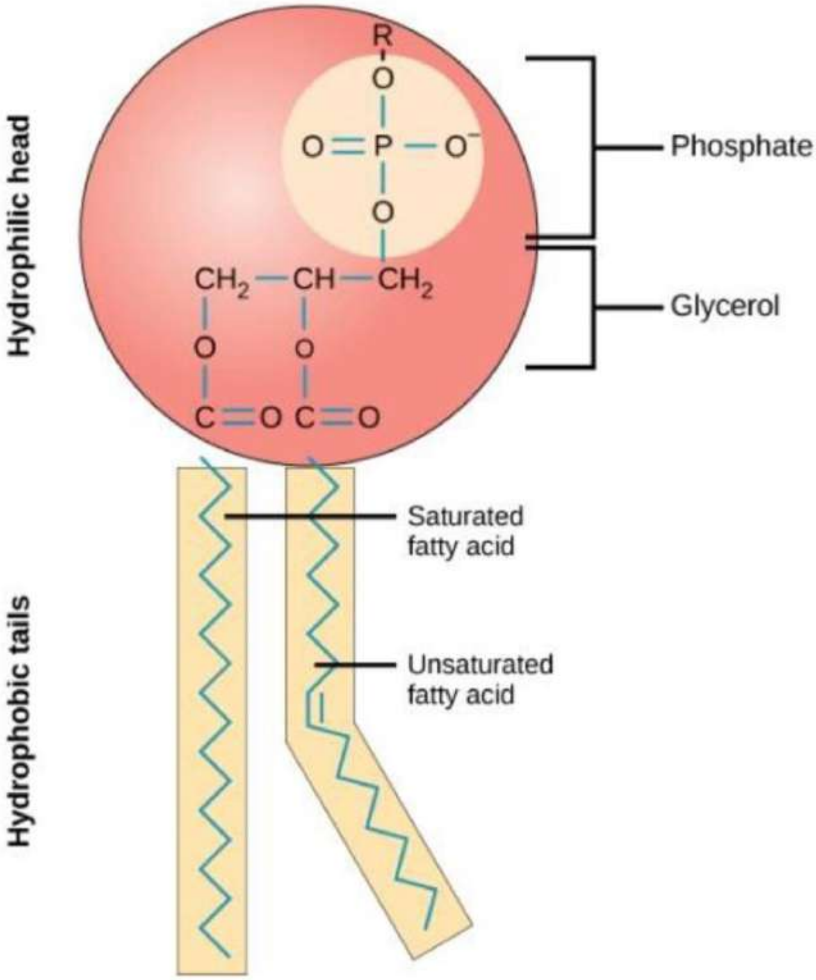
(Figure 3)

Phospholipid structure consists of

One **Phosphate group** attached to the glycerol.

One **glycerol**– a 3-carbon polyalcohol acting as a backbone for the phospholipid.

Two **fatty acids** attached to the glycerol.



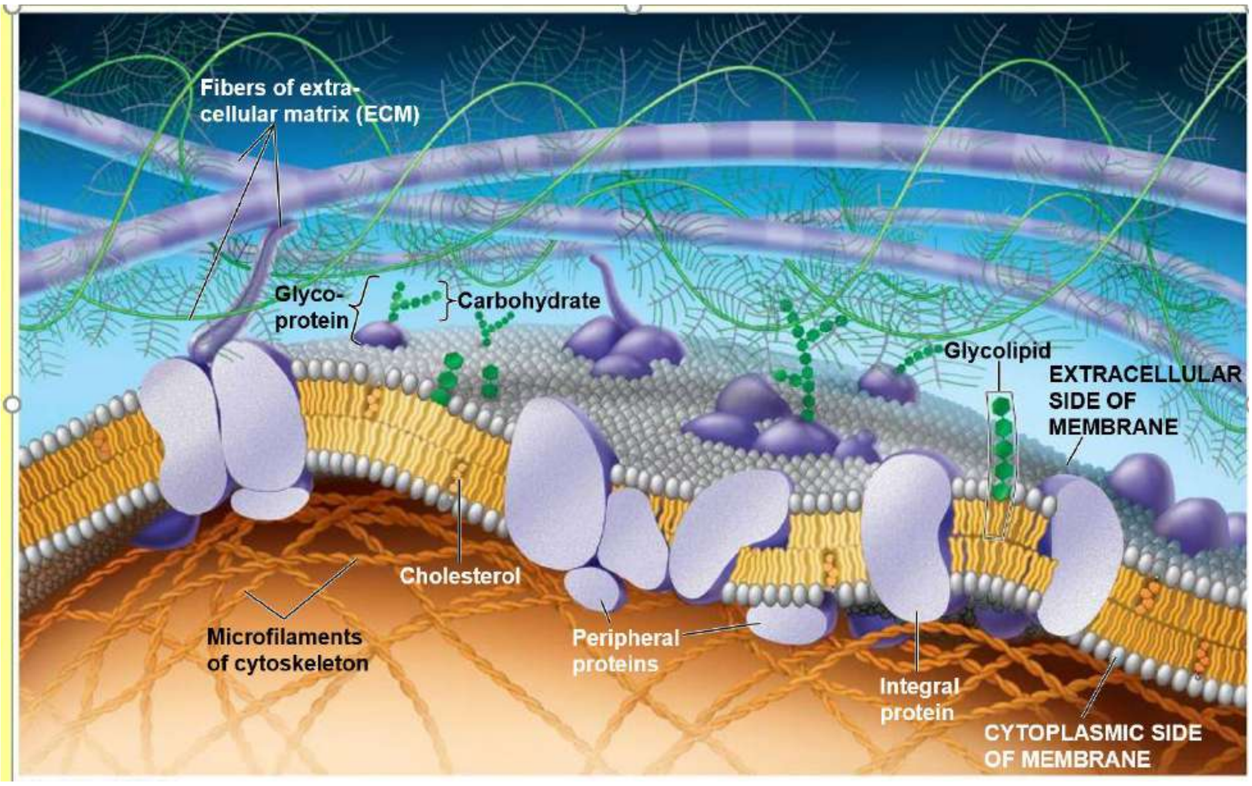
(Figure 4)

2- Transmembrane proteins (Integral membrane protein).

A transmembrane protein (TP) is a type of integral membrane protein that spans the entirety of the cell membrane. Many transmembrane proteins function as gateways to permit the transport of specific substances across the membrane. Integral membrane proteins are embedded in the phospholipid bilayer. Most integral proteins contain residues (amino acids) with hydrophobic side chains that interact with fatty acyl groups of the membrane phospholipids, thus anchoring the protein to the membrane. Most integral proteins span the entire phospholipid bilayer **(See Fig 5)**.

3- Interior protein network (Peripheral membrane proteins.

Peripheral membrane proteins **DON'T** interact with the hydrophobic core of the phospholipid bilayer. Instead they are usually bound to the membrane indirectly by interactions with integral membrane proteins or directly by interactions with lipid polar head groups **(See Fig 5)**.

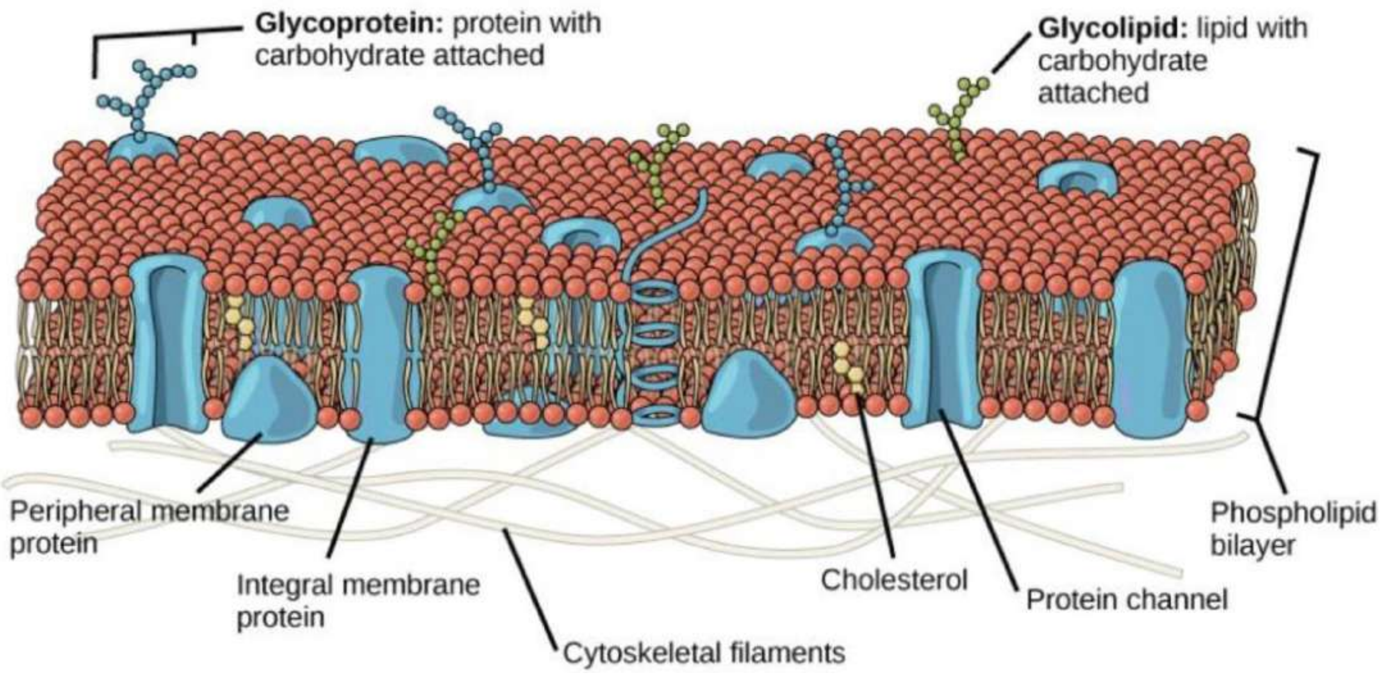


(Figure 5)

4- Cell surface markers.

Cell surface markers are special proteins and carbohydrates attached to the cell membrane. While some proteins have the task of allowing the transport of molecules across the membrane, cell surface markers play a role in inter-cellular communication and recognition. In short, cell surface markers are like a fingerprint, specific to each kind of cell, and capable of being identified according to what kinds of markers are present on the membrane.

Other molecules found in the membrane include **Cholesterol, Glycolipids and Glycoproteins**, some of which are shown in figure below. Cholesterol, a type of lipid, makes the membrane a little stronger (**See Fig 6**).



(Fig 6)

The membrane is semi-permeable, and selectively permeable, in that it can either let a substance (molecule or ion) pass through freely, pass through to a limited extent or not pass through at all. Cell surface membranes also contain receptor proteins that allow cells to detect external signalling molecules such as hormones.

The function of the plasma membrane proteins

1- Channel proteins: allows H ions to flow across the inner mitochondria membrane. Without this movement of H ions ATP would never be produce.

2- Carrier proteins: -Transport sodium and potassium ions across the plasma membrane of a nerve cell without this carrier protein nerve impulse conduction with impossible.

3-Cell recognition proteins: - recognized pathogen.

4- Receptor proteins

5- Enzymatic protein

6-Junction proteins structures that allow cells to interact with each other, there are three type of junctions

***Adherents junctions, (anchoring junctions)**

***Gap junctions) (communicating junction)**

***Tight junctions (occluding junctions).**

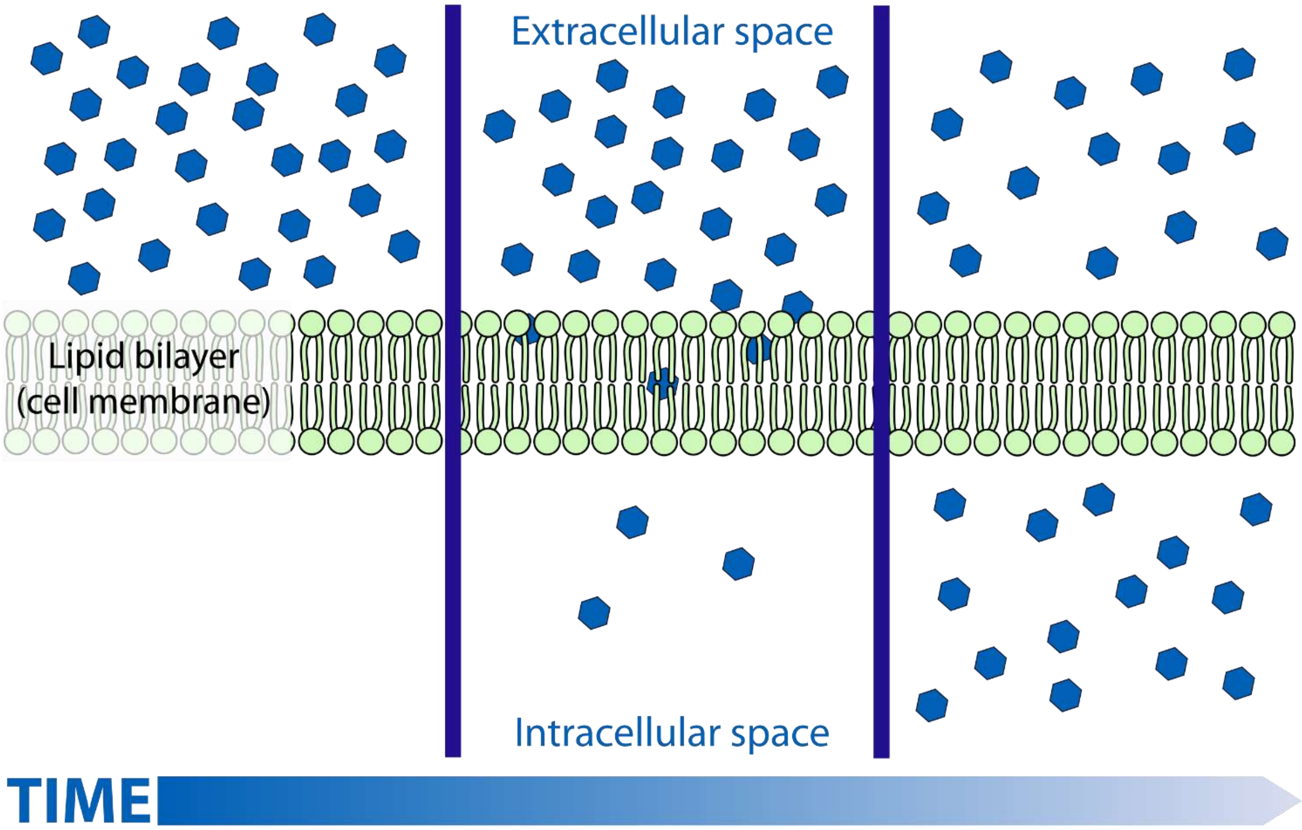
Cell Transport

What is cell transport? It is the movement of substances across the cell membrane either into or out of the cell. Sometimes things just move through the phospholipid bilayer. Other times, substances need the assistance of a protein, like a channel protein or some other transmembrane protein, to cross the cell membrane. Cell transport includes passive, active and Bulk transport.

A- Passive transport is a movement of ions and other atomic or molecular substance across cell membranes without need of energy input. It does not require an input of cellular energy because it is instead driven by the tendency of the system to grow in entropy. The rate of passive transport depends on the permeability of the cell membrane, which, in turn, depends on the organization and characteristics of the membrane lipids and proteins. The four main kinds of passive transport are:

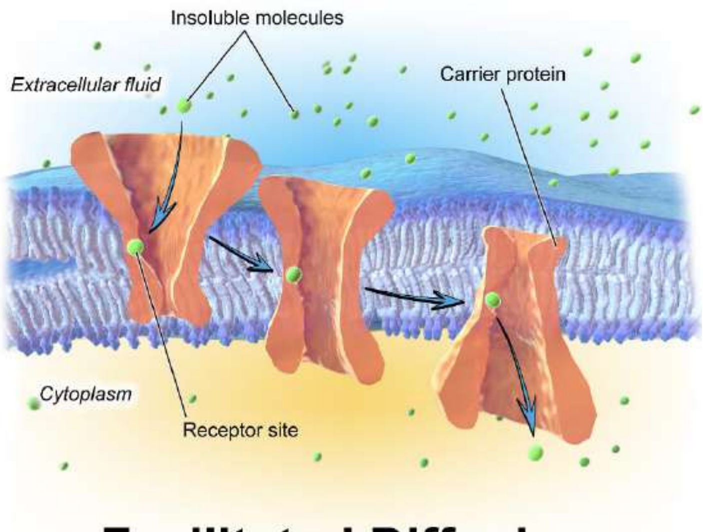
1- Simple diffusion

Diffusion is the net movement of material from an area of high concentration to an area with lower concentration. The difference of concentration between the two areas is often termed as the concentration gradient, and diffusion will continue until this gradient has been eliminated (See Fig below).



2- Facilitated diffusion.

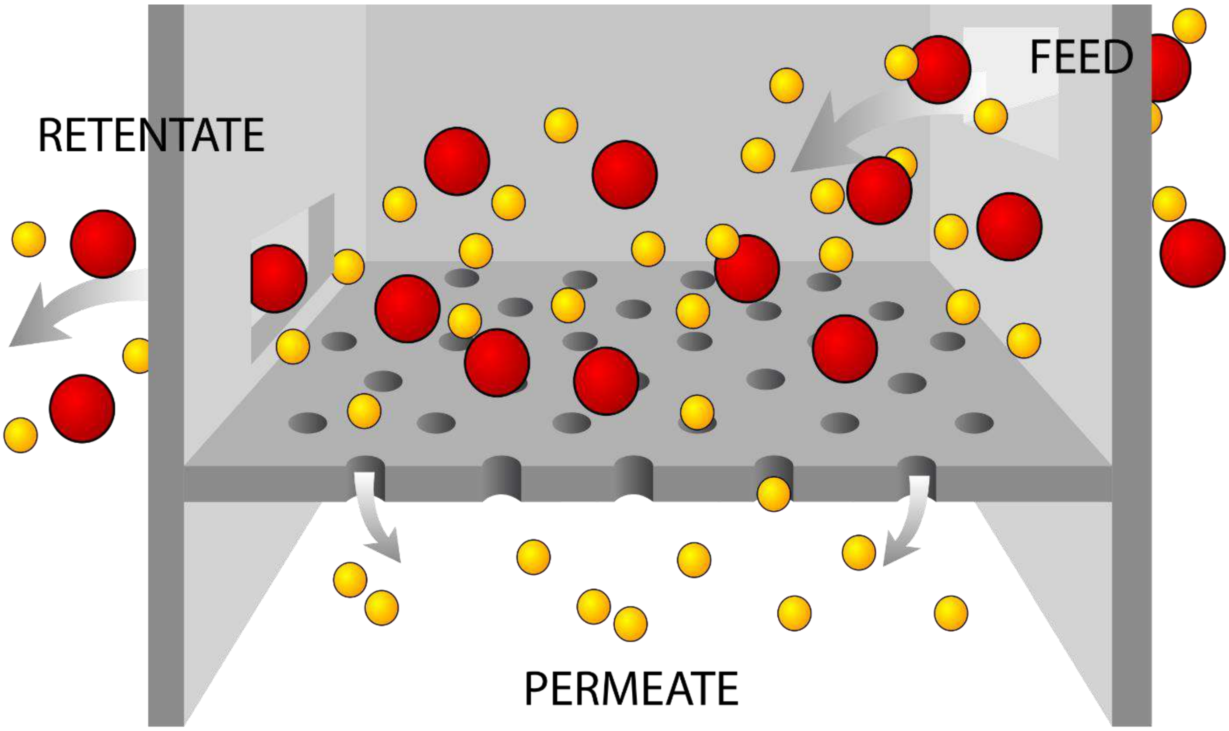
Facilitated diffusion, also called carrier-mediated osmosis, is the movement of molecules across the cell membrane via special transport proteins that are embedded in the plasma membrane by actively taking up or excluding ions (See Fig below).



Facilitated Diffusion

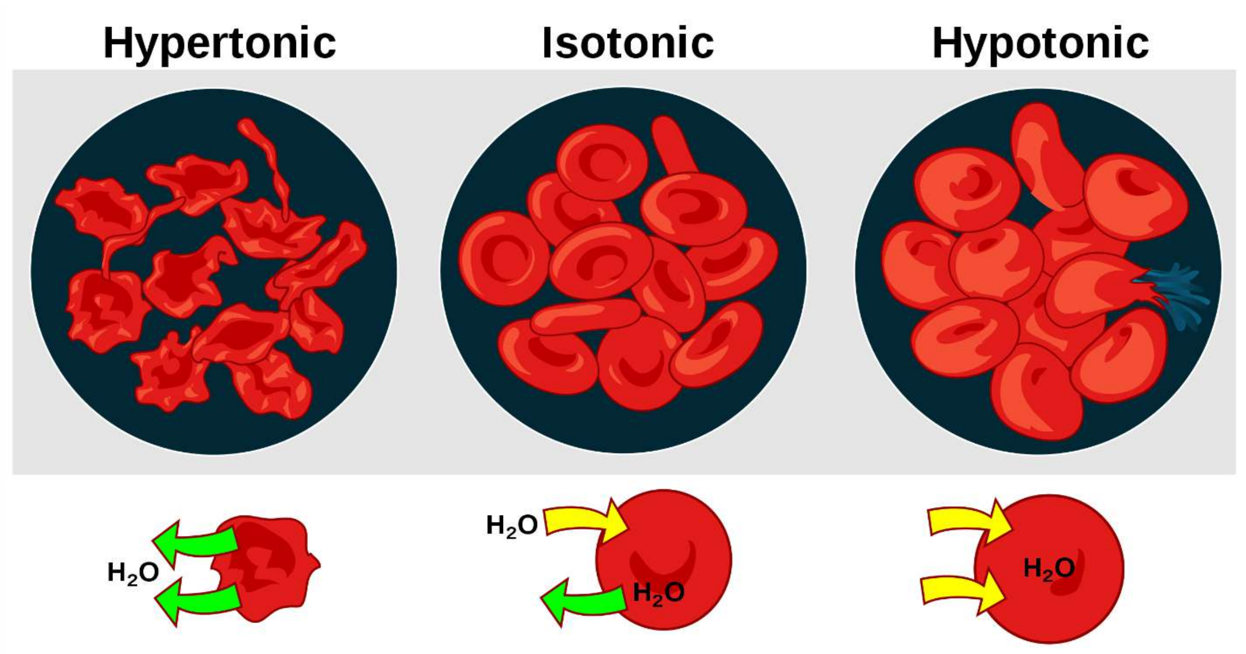
3- Filtration.

Filtration is movement of water and solute molecules across the cell membrane due to hydrostatic pressure generated by the cardiovascular system. Depending on the size of the membrane pores, only solutes of a certain size may pass through it. For example, the membrane pores of the Bowman's capsule in the kidneys are very small, and only albumins, the smallest of the proteins, have any chance of being filtered through. On the other hand, the membrane pores of liver cells are extremely large, but not forgetting cells are extremely small to allow a variety of solutes to pass through and be metabolized (See Fig below).



4- Osmosis.

Osmosis is the movement of water molecules across a selectively permeable membrane. The net movement of water molecules through a partially permeable membrane from a solution of high-water potential to an area of low water potential. A cell with a less negative water potential will draw in water (Water moves from areas of where water potential is higher (or less negative), to areas where it is lower (or more negative)),but this depends on other factors as well such as solute potential (pressure in the cell e.g. solute molecules) and pressure potential (external pressure e.g. cell wall). There are three types of Osmosis solutions: the isotonic solution, hypotonic solution, and hypertonic solution. Isotonic solution is when the extracellular solute concentration is balanced with the concentration inside the cell. In the Isotonic solution, the water molecules still move between the solutions, but the rates are the same from both directions, thus the water movement is balanced between the inside of the cell as well as the outside of the cell. A hypotonic solution is when the solute concentration outside the cell is lower than the concentration inside the cell. In hypotonic solutions, the water moves into the cell, down its concentration gradient (from higher to lower water concentrations). That can cause the cell to swell. Cells that don't have a cell wall, such as animal cells, could burst in this solution. A hypertonic solution is when the solute concentration is higher (think of hyper - as high) than the concentration inside the cell. In hypertonic solution, the water will move out, causing the cell to shrink (See Fig below).



B- Active transport

Carrier proteins used in active transport include:

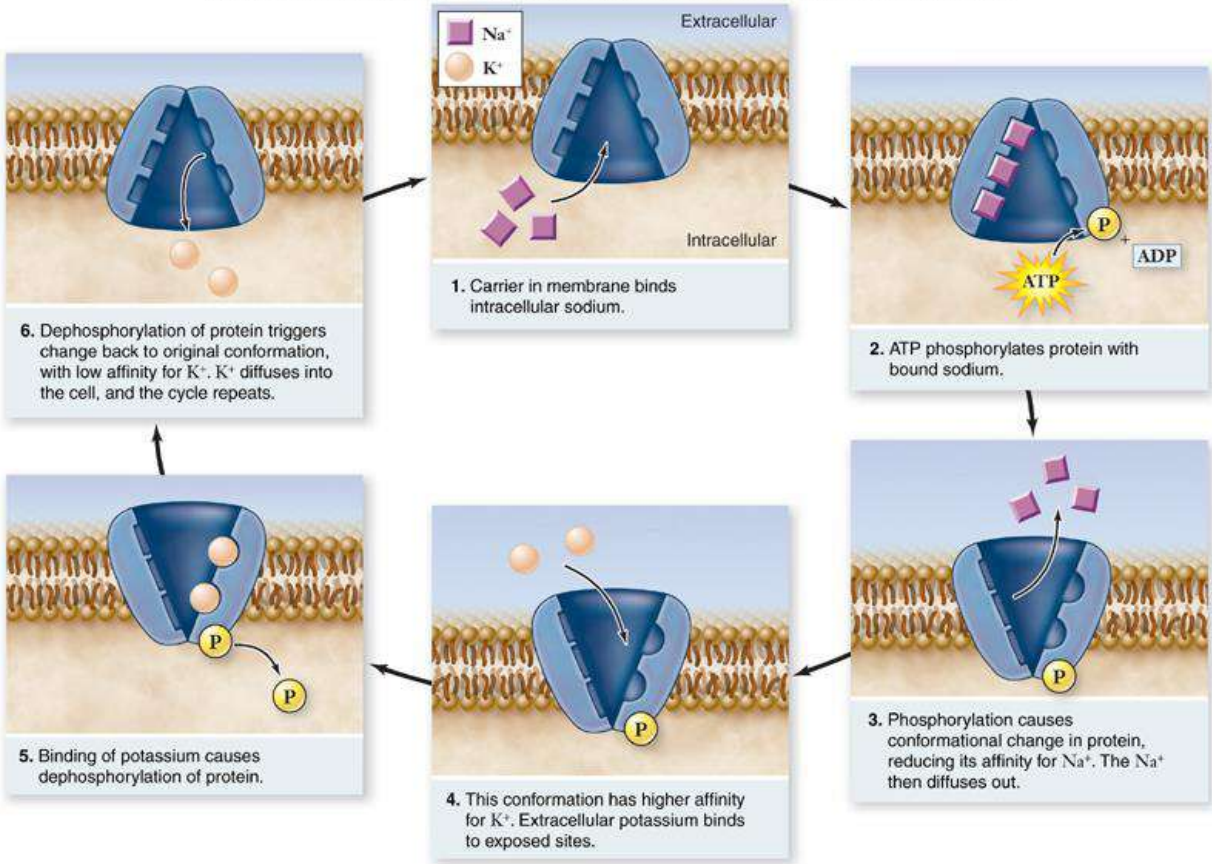
1- Uniporters – move one molecule at a time
2- Symporters – move two molecules in the same direction
3- Antiporters – move two molecules in opposite directions

For example:

First example of Uniporters is the glucose transporter that is found in erythrocytes.

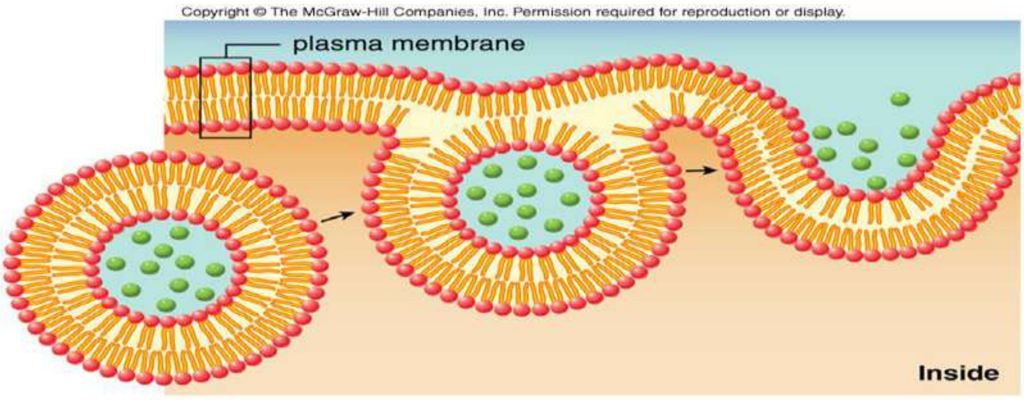
Second example of Symporter is the glucose symporter SGLT1 (Sodium-glucose transport proteins), which co-transport one glucose (or galactose) molecule into the cell for every two sodium ions that is imports into the cell. This symporter is located in the small intestines, heart, and brain.

Third example of antiporters is Sodium-potassium (Na^+-K^+) pump which is used to move 3 Na^+ out of the cell and 2 K^+ into the cell



C-Bulk transport

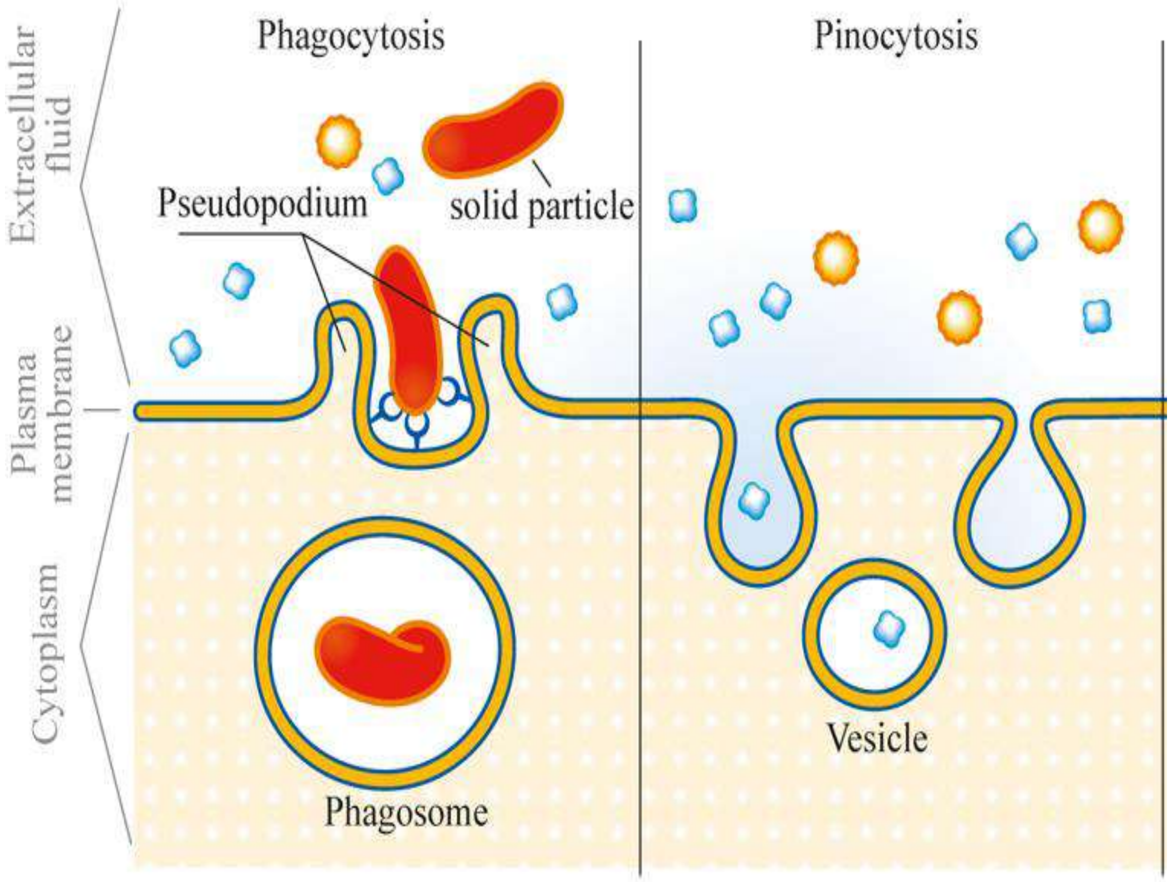
Endocytosis and **exocytosis** are both forms of bulk transport that move materials into and out of cells, respectively, via vesicles. In the case of endocytosis, the cellular membrane folds around the desired materials outside the cell. The ingested particle becomes trapped within a pouch, known as a vesicle, inside the cytoplasm. Often enzymes from lysosomes are then used to digest the molecules absorbed by this process. Substances that enter the cell via signal mediated electrolysis include proteins, hormones and growth and stabilization factors. Viruses enter cells through a form of endocytosis that involves their outer membrane fusing with the membrane of the cell (See Fig below).



a. Exocytosis

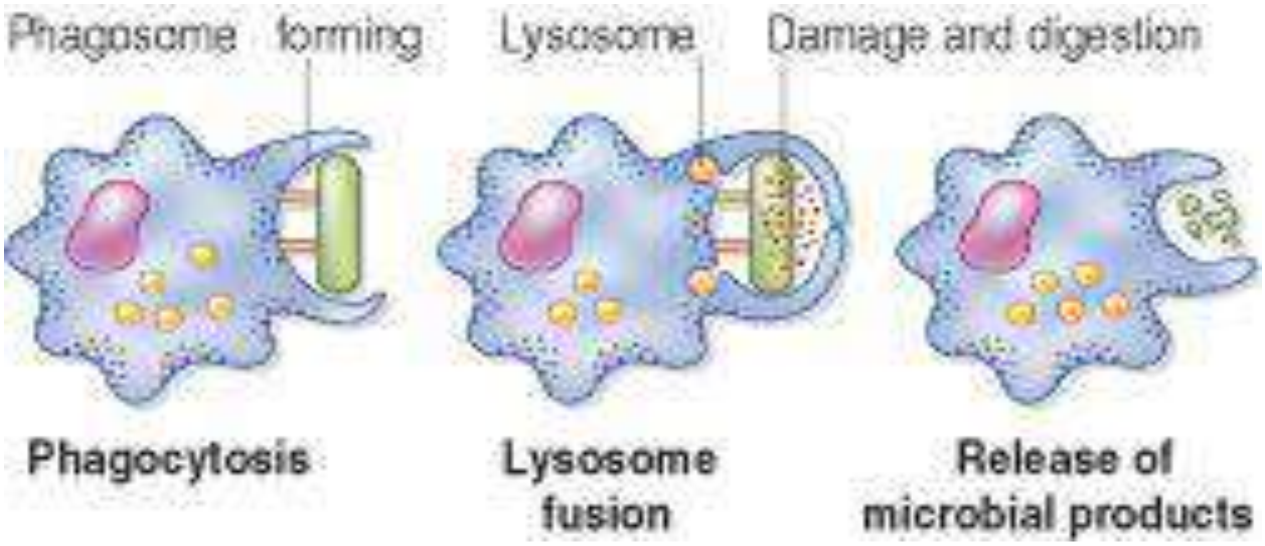
Biologists distinguish two main types of endocytosis: **pinocytosis** and **phagocytosis**.

In pinocytosis, cells engulf liquid particles (in humans this process occurs in the small intestine, where cells engulf fat droplets). In phagocytosis, cells engulf solid particles



Phagocytosis:

In a multicellular organism's immune system, phagocytosis is a major mechanism used to remove pathogens and cell debris. The ingested material is then digested in the phagosome. Bacteria, dead tissue cells, and small mineral particles are all examples of objects that may be phagocytized. Some protozoa use phagocytosis as means to obtain nutrients.



References

1- Molecular cell biology

Molecular Cell Biology Fifth Edition by Lodish, Harvey; Berk, Arnold; Matsudaira, Paul; Kaiser, Chri published by W. H. Freeman Hardcover.**2008 - Macmillan**

2- Molecular Biology

Fifth Edition R o b e r t F. We a v e r University of Kansas

Medical Biology

Dr. Waleed K Mohammed and Dr. Karama .T.l-Taee

05 /11/2019 Lecture 1

General introduction

WHAT IS BIOLOGY?

The science which deals with the study of living objects and their life processes is called biology (Greek words, bios – life, logos – study). It covers all aspect of the study of living creatures like occurrence, classification, ecology, economic importance, external form, organization, internal structure, nutrition, health and other.

Branches of Biology:

There are three major branches of biology – botany, zoology and microbiology. **Botany** is the branch of biology which deals with the study of different aspects of plants.

Zoology is the branch of biology connected with the study of different aspects of animals. Aristotle is known as the father of Zoology.

Microbiology is the branch of biology dealing with the study of different aspects of microorganism. Leeuwenhoek is known as the father of Microbiology.

MAIN BRANCHES OF BIOLOGY

Some of the main branches of biology are briefly discussed below:

1. **Taxonomy:** It is the science of identification, nomenclature and classification of organisms.
2. **Morphology:** It is the study of external form, size, shape, colour, structure and relative position of various living organ of living beings.
3. **Anatomy:** It is the study of internal structure which can be observed with unaided eye after dissection.
4. **Histology:** It is the study of tissue organization and structure as observed through light microscope.
5. **Cytology:** It is the study of form and structure of cells including the behaviour of nucleus and other organelles
6. **Cell Biology:** It is the study of morphological, organizational, biochemical, physiological, genetic, developmental, pathological and evolutionary aspects of cell and its components.
7. **Molecular Biology:** It is the study of the nature, physicochemical

organization, synthesis working and interaction of biomolecules that bring about and control various activities of the protoplasm.

8. **Physiology:** It is the study of different types of body functions and processes.
9. **Embryology:** It is the study of fertilization, growth, division and differentiation of the zygote into embryo or early development of living beings before the attainment of structure and size of the offspring.
10. **Ecology:** It is the study of living organisms is relation to other organism and their environment.
11. **Genetics:** It is the study of inheritance of characters or heredity and variations. Heredity is the study of expression and transmission of traits from parents to offspring.
12. **Evolution:** It studies the origin of life as well as new types of organism from the previous ones by modifications involving genetic changes and adaptations.
13. **Virology:** It is the study of viruses in all their aspects.

General characteristics of living things

When examining the characteristics of organisms, there are two basic categories of organisms- **living** and **non-living**. There are several characteristics that exist to classify an organism as a living thing. Living organisms must be made of cells, reproduce, use energy, grow and develop, respond to stimuli, adapt to their environment, and maintain homeostasis. Non-living organisms, then, lack one or more of these characteristics. For example, plants and animals are living while rocks and cars are not living. It is important to understand the basic characteristics of organisms because these features determine how scientists classify, study and discuss all matter. Because of this information, all living matter can be classified in a complex taxonomy system that shaped the way organisms are named and studied.

These are the three characteristics of living organisms.

1- **Living things are organized**
2- **Living things obtain and use energy**
3- **Living things Maintain Homeostasis.**
4- **Reproduction.**
5- **Living things adaptations**

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1- Living things are organized: - The levels of organization began with atoms which are the basic units of matters, atoms combine with other atoms of the same or different elements to form molecules. The cell composed of variety of molecules working to gather, organism may be **Unicellular, paramecia _ Multicellular, human.** Many living things that are unicellular – they consist of a single cell. Other living things are multicellular, consisting of many cells – many trillions of cells in the case of human adult. The cell is in several senses the basic unit of a living organism. There are more than 200 distinct kinds of cells in the human body. All living things are composed of cells, and all cells arise from pre-existing cells

Similar cells combine to form tissue (nerve tissue), tissue make up organs (brain), organs work to gather in system (brain work with spinal cord and a network of nerves to form nervous system). Organ systems are joined to gather to form a complete living organism such as a human.

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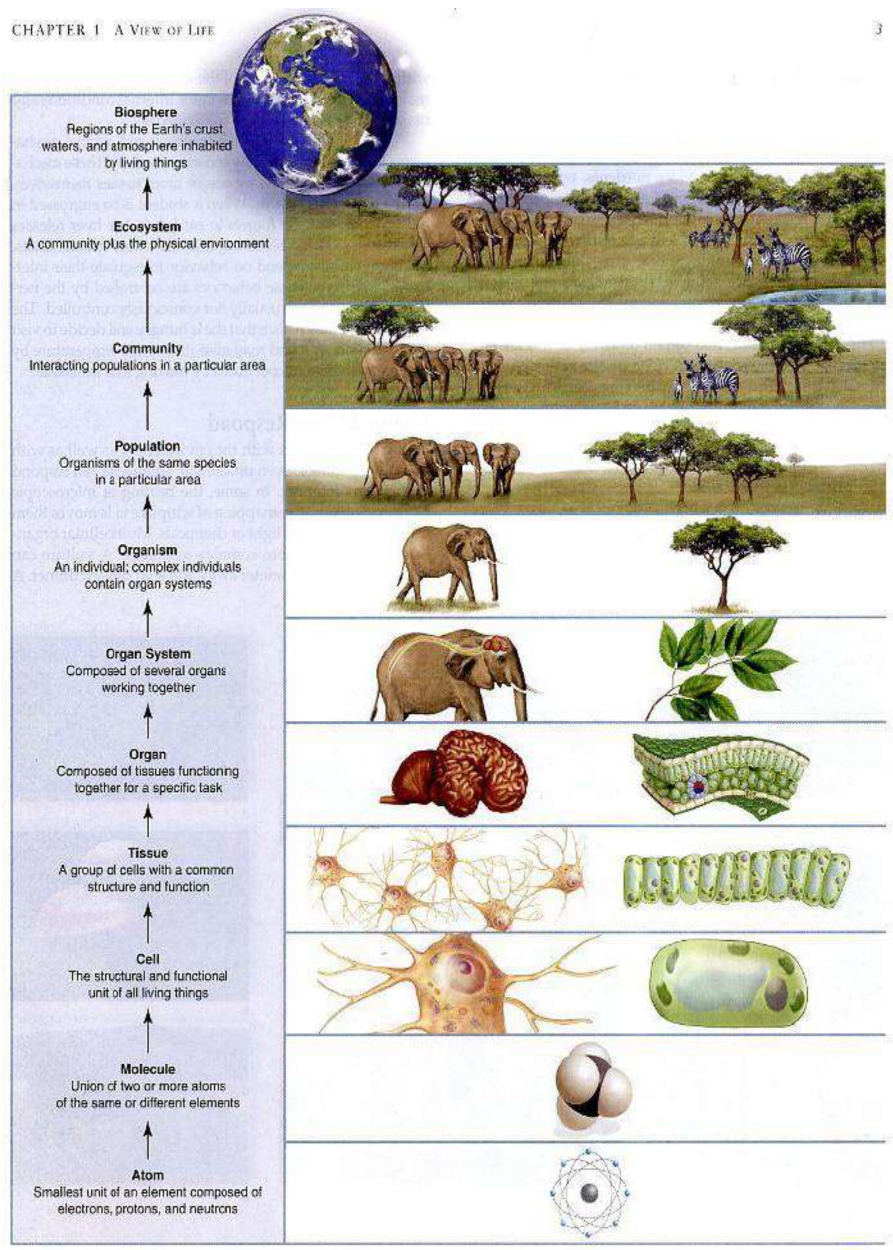
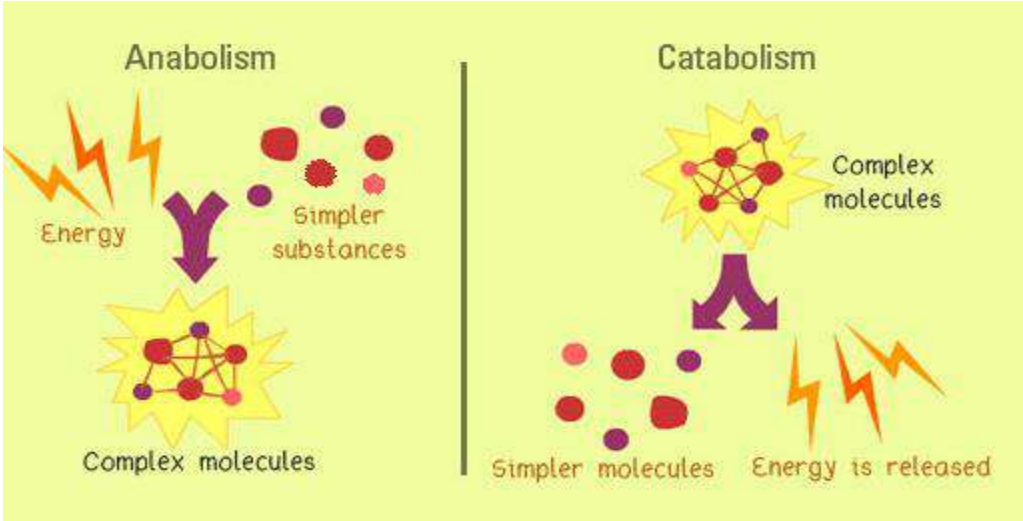


2- Living things obtain and use energy: - Cells cannot survive on their own. They need power to stay alive. They need energy to perform functions such as growth, maintaining balance, repair, reproduction, movement and defence. This means all living organisms must obtain and use energy to live.

Energy is the power to do things. This power comes in many ways and forms, but they can all be linked to the sun. It is the source of all energy.

The process of obtaining and using energy by living organisms are best explained by three important scientific terms namely **Anabolism, Catabolism and Metabolism**.



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❖ **Anabolism (constructive anabolism)**

This is a process whereby living organisms use simpler substances to put together, or build complex substances such as carbohydrates, proteins and fats for storage. Such an activity is known as an anabolic activity. **Nutrition** is anabolism process as it helps in the building up of the body tissue.

A living organism can either make its own food or depend on others to make food for them. For example, green plants produce their own food from a process called photosynthesis. They use the chloroplasts in their cells to capture energy in sunlight. They combine it with water and carbon dioxide from the air to produce sugars for themselves. Other organisms take diffusible and non- diffusible complex organic substance as food (**ingestion**) in animals. The non-diffusible foods substance is converted into diffusible forms (**digestion**). The digestion food is absorbed and distributed in to various parts of the body and is ultimately converted into protoplasm (assimilation). The undigested waste matter is passed out of the body as feces (egestion) or defecation

❖ **Catabolism (destructive catabolism)**

This is when the cells in living organisms, breakdown complex substances and molecules into simpler substances, often to release energy for use.

❖ **Respiration**

a catabolism process as it tends to destroy the tissue substances by oxidation. It involves intake the oxygen and outgo of carbon dioxide. Oxygen oxidizes the tissue substances, CO_2 and water are produced and energy is liberated. This energy is utilized for performance of various bodily functions.

- ❖ **Metabolism**

This is the sum of all the chemical reactions (anabolic and catabolic activities) that go on in the cells of living organisms. It is a continuous process because the moment metabolism stops, the living organism will die.

3-Living things Maintain Homeostasis :-To survive it is imperative that an organism maintain a stat of biological balance or homeostasis ,temperature , moisture level, acidity or other physiological factors must remain within the tolerance range of the organism .Homeostasis is maintained by systems that monitor internal conditions and make routine and necessary adjustments .

Examples of homeostasis include the regulation of body temperature, the pH of extracellular fluid, or the concentrations of sodium, potassium and calcium ions. Muscular activity generates heat as a waste product .This heat is removed from our bodies by sweating .

pH :- In human pH need to be maintained within a narrow range .The pH of blood is 7.4 that is slightly basic (alkaline) .If the blood pH drops to about 7 acidosis results .If the blood pH rises to about 7.8 alkalosis results .Both conditions can be life threatening , so the blood must be kept around 7.4 .

Carbonic acid is a weak acid that minimally dissociate and then re-forms in the following manner :

H_2CO_3 ------dissociates----------- H^+ + HCO_3^-

Carbonic acid ------re-forms------ Bicarbonate ion

Blood always contains a combination of some carbonic acid and some bicarbonate ion. When hydrogen ion H^+ are added to blood the following reaction reduces acidity

H^+ + HCO_3^- -------------------- H_2CO_3

When hydroxide ions OH- are added to blood ,this reaction reduces basicity .

OH- + H2CO3 ----------------------- HCO3- + H2O

These reactions prevent any significant changes in blood pH.

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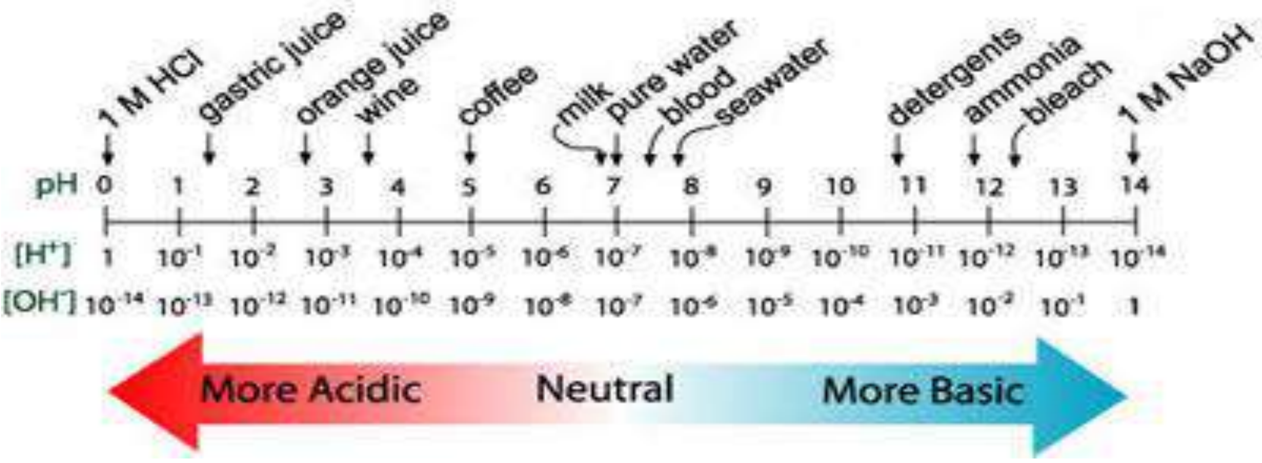

4-Reproduction: - is the process through which new organisms, or offspring, are produced by a parent organism.

Asexual reproduction (fission ,budding and fragmentation) involves **one parent** organism and produces an **identical offspring**. Bacteria reproduce **asexually** as well as some animals such as starfish that use asexual reproduction to regenerate limbs.

Sexual reproduction involves **two parent** organisms and produces a genetic combination of the two. In sexual reproduction, the offspring has a **unique genetic code** because of the variety of combinations that could occur from parents. Most living organism use the chemical DNA (deoxyribonucleic acid) as the physical carrier of inheritance and the genetic information .Some organisms such as retrovirus (of which HIV is a member) use RNA (ribonucleic acid) as the carrier .

5-Living things adaptations:- adaptations are modification that make organism better able to function in a particular environment , penguins are adapted to an aquatic existence in the Antarctic . An extra layer of downy feathers is covered by short , thick feathers that form a waterproof coat ,feet and tails serves as rudders in the water .flat feet also allow them to walk on land . a polar bear has very thick fur to trap their body heat in the cold artic temperatures

6- Living things respond: - In order to survive, living things must respond to stimuli in their environment. This responsiveness is active and requires a set of systems to detect a change and respond to it. Living things change according the light, temperature, and chemicals in their environment. An example of this would be a person touching a hot stove and immediately pulling their hand away.

7- Excretion: - All living things excrete. As a result of the many chemical reactions occurring in cells, they have to get rid of waste products which might poison the cells. Excretion is defined as the removal of toxic materials, the waste products of metabolism and substances in excess from the body of an organism.

8- Secretion:- The living things produce many useful substances such as enzymes ,hormones….etc. These substances are produced in different parts of body and are sent to other parts.

9- Growth and development: -. Growth can be the adding of cells to an organism to cause it to change in size or mass. This can also be exhibited in the change of appearance or form. For example, tadpoles develop into frogs with the addition of cells and the change of appearance.

10- Movement or motility: - Most of the animals move bodily from one place to another with the help of certain organs or organelles, this called ***locomotion***.

11-Interactions: - living things interact with their environment as well as each other. Organisms obtain raw materials and energy from the environment or another organism. The various types of symbioses (organismal interactions with each other) are examples of this interaction .

Symbiosis: - An interaction between two or more species living together, may be **parasitic**, commensal or **mutualism**, The relationship between two organism .

12-Death: - Living things ultimately suffer from death.

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The Structure of Prokaryote and Eukaryote Cells

Prokaryotes are simple, small cells, whereas **eukaryotic cells** are complex, large structured and are present in trillions which can be single celled or multicellular. Prokaryotic cells do not have a **well-defined nucleus,** but DNA molecule is in the cell, termed as **nucleoid**, whereas eukaryotic cells have a **well-defined nucleus**, where genetic material is stored. Based on the structure and functions, cells are broadly classified as Prokaryotic cell and Eukaryotic cell

Prokaryotic Cells are the most primitive kind of cells and lack few features as compared to the eukaryotic cell. **Eukaryotic cells** have evolved from prokaryotic cells only but contain different types of organelles like Endoplasmic reticulum, Golgi body, Mitochondria etc, which are specific in their functions. But features like growth, response, and most importantly giving birth to the young ones are the commonly shared by all living organisms.

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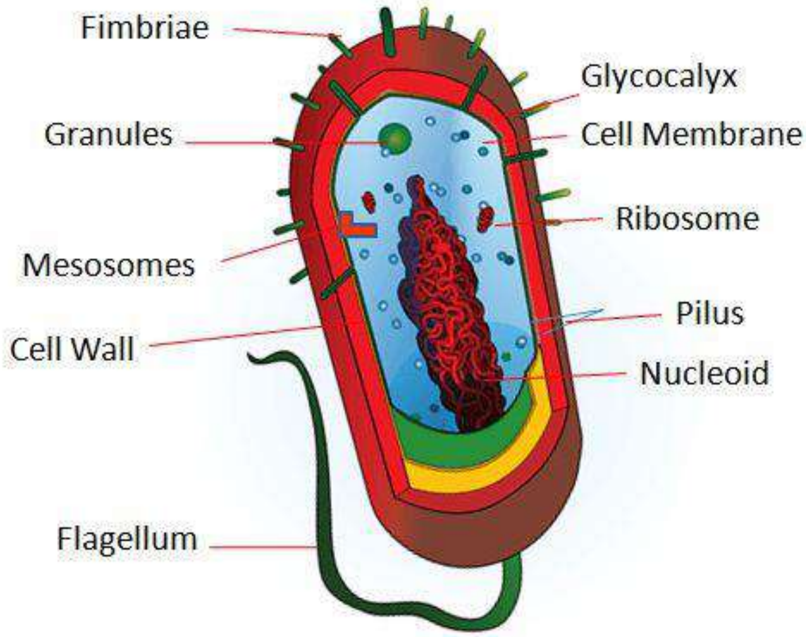

General structure of Prokaryotic Cells

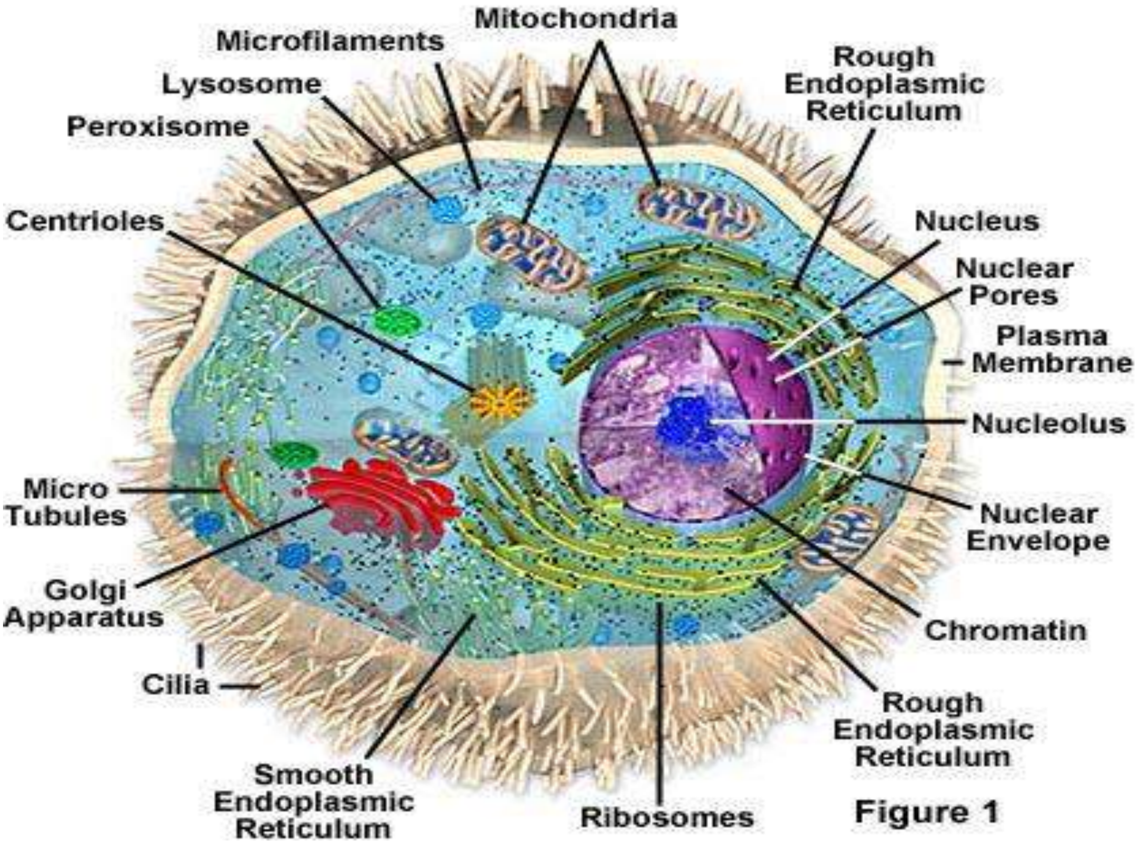

Figure 1

Classification of Living Organisms the Taxonomic System

Domain is the largest classifying system. There are three domains that contain all the known living organisms on the planet.

I-The domain Eukarya contains **plants**, **animals**, **fungi**, and **protists**.

II-The domain Bacteria contains **cyanobacteria** and **heterotrophi**c bacteria.

III- The l domain, Archaea, contains **halophiles** and **thermophiles**, which are not bacteria.

Archaea are organisms that survive in the most extreme environments on the planet such as thermal vents that reach over 100 degrees Celsius

There are four Kingdoms: Protista, Fungi, Plantae, and Animalia.

Kingdom Protista: - contains protists that are usually single-celled organisms such as algae.

Kingdom Fungi:- contains decomposers such as fungi, yeast, and mold.

Kingdom Plants:- that have chlorophyll, cell walls and vacuoles can be classified in Kingdom Plantae.

Kingdom Animalia:- contains any animal that survives by eating other organisms. Animals cannot produce their own food, therefore they rely on other plants and animals to serve as their food source. From there each Kingdom is broken down further into **Phylum**, **Class**, **Order**, **Family**, **Genus**, and **Species**.

Binomial nomenclature. This format uses the Genus and Species to give animals their distinct scientific name. For example, human would be the familiar name while *Homo sapiens* is the scientific name.

Kingdom: *Animalia*

Phylum: *Chordata*

Subphylum: *Vertebrata*

Class: *Mammalia*

Order: *Primates*

Suborder: *Anthropoidea*

Superfamily: *Hominoidea*

Family: *Hominidae*

Genus: *Homo*

Species: *sapiens*

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